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Abstract

Since the USA Telecommunications Act of 1996, the regulatory frameworks, have led to the requirement of different policy practices in many countries across the world in order to establish sustainable competition in whole telecommunication markets. These regulatory reforms are the privatization of the telecom historical integrated monopoly (the incumbent), the independency of the regulatory authority, the obligation of transparency of the access price and agreements & the unbundling, the separation and the access pricing policies. This paper suggests an empirical investigation on both the individual, and the global impacts of these different regulatory policy practices on broadband deployment. To this end, we construct a panel data covering 107 developed and developing countries over the period of eight years from 2004 to 2011. Using the Instrumental variables (IV) & the Generalized Method of Moments (GMM) with fixed effects and robust to heteroskedastic and autocorrelated errors, we show that the relationship between regulation and broadband investment is an inverted U shape in developed world while it takes a U form in developing countries. This means that in developed countries, a less restrictive regulatory policy spurs broadband deployment while more stringent policy discourages innovation in telecom industry. However, in the developing countries, the regulation has a strict negative impact on broadband deployment.

***Key Words**:* developed and developing countries, regulation, fixed broadband deployment, separation, unbundling, access pricing.
JEL Codes: C51, L59, L96

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1 Introduction

The apparition of the technologies of the digitalization at the beginning of 1990s has led to the emergence of platforms with high capacities of data transmission (the broadband technologies) (ITU 2012). Compared to the traditional infrastructure technologies (copper telephone lines),the fixed broadband platforms (the fiber optic and the digital subscriber lines DSL), as well as, the mobile broadband technologies (satellite, Third and Fourth Generation mobile 3G & 4G) allow users to access to various voice and data services with high qualities [1] (Fornefeld, Delaunay and Elixmann 2008). Economic literature (see for e.g., Yongsoo, Tim and Siddhartha 2010; Qiang and Rossotto 2009; Koutroumpis 2009) shows evidence about the increasing role of the investment in these advanced telecommunication infrastructures (broadband technologies) in driving growth, employment and economic development.

Fixed broadband infrastructures provide better quality of services but their diffusion is still relatively limited compared to mobile broadband technologies (Kumar 2012). The number of mobile broadband subscriptions is about three times greater than the number of fixed broadband subscriptions in 2013 (ITU 2014). The large costs of fixed infrastructure investment explain the slow diffusion and the tardiness of market developments of fixed telecommunication technologies compared to mobile ones.

The large amounts of investments required to build these fixed network lines (the local loop) have constituted crucial barriers to entry into telecommunication markets, and thereby; justify the dominance of the monopoly structure in the past, as well as, the difficulty that the policy makers (governments, regulators) actually faces to establish sustainable competition in the fixed telecommunication market segments in order to let consumers benefit from diversities in service qualities and cost reductions resulting from technology progress.

During the last two decades, the regulation has played a major role to force the transition toward competition telecommunication markets through mandating the policy reforms suggested by 1996 Act that lead to the World Trade Organization (WTO) Reference Paper in 1998.

WTO Reference Paper is a “global consensus” or Agreement on Basic Telecommunications (BTA), that countries members or aiming at became members of WTO should follow (Guermazi 2004; David 1997; ITU 2013). It contains a number of guidelines, which aim at ensuring the world wide connectivity through promoting liberalization and competition in telecommunication markets by requiring rules that permit to avoid anticompetitive behaviors (Cowhey and Klimenko 2001).

Four major topics and principles are included in the BTA[2] that policy makers should follow to construct their regulatory frameworks, among that:

- The obligation to countries members to establish an independent national regulatory authority (NRA), that must be independent from government and ministries and exercise their responsibilities in entire autonomy.

- The obligation to regulate the use in efficient and equitably manner the scarce resources by different operators.
- The obligation of provision of universal services by incumbent firm (the historical integrated monopoly) to end-users of new entrants having the same characteristics (quality, etc.) that those offered to incumbent’s end-users.
- The obligation of the “Major Supplier” (usually the historical integrated monopoly) to offer access to their network infrastructure facilities (interconnection) at non-discriminatory conditions (non-discriminatory principle) and to publish these interconnection offers (principle of transparency). The

[1] In general, a high quality implies high speeds of connection (i.e., Reduced time of download and upload waiting). Among high quality services, we cite for example, multimedia applications such as video conferencing, real-time audio streaming, 3-D applications, telemedicine, video TV movies, Internet Protocol telephony, etc.)
[2] See Guermazi (2004), David (1997) and ITU (2013) .

major supplier is the dominant operator, the owner of essential facilities (the telecommunications infrastructures) that constitute a necessary input to provide end-users services. Interconnection conditions or offers concern the access quality (technical modalities of network access, ..) and the price of access to the network service provided to new entrants by the dominant operator, which is generally the historical integrated monopoly (the incumbent). The last obligation of the BTA is the key to the creation of the competition in end-users services fixed telecommunications markets segments. It aims at permitting to new entrants to share the existent network infrastructures owned by the incumbent at non-discriminatory access terms.

According to WTO Reference Paper, the regulators must prevent (ex ante regulation) and avoid (ex poste regulation) the anti-competitors behaviors of the major supplier (the owner of infrastructure facilities) by applying the appropriate policy practices. The regulatory frameworks, have led to various regulatory access practices including different forms of technical modalities to access to the incumbent's network infrastructures (the unbundling access policies), different models of access pricing determination and various models of organization structure of the incumbent firm (separation policies). The countries having the most developed telecommunications markets, including the United States American (USA), those member of the European Union (EU), Japan and Australia are the firsts that are applied these reforms. For developing countries, implementing WTO Reference Paper requirements by national governments is seen necessary to attract both domestic and foreign investments in telecommunications (David 1997). In particular, Middle East, Asia Pacific, Africa, Latin America and Caribbean countries follow the EU model for Access regulatory measures[3], which is considered a middle approach between the full deregulation model of the USA and the interventionist model of Japan and South Korea (Cambini and Jiang 2009).

The role of the regulation in driving investment in new technologies by both incumbent (upgrading the existent networks) and entrants (building new networks) is recently subjects of an extensive debate. Theoretical literature points out on the competition-investment dilemma: access regulation promotes competition but may impede investment in network infrastructures (e.g., Laffont and Tirole 2000; Bourreau, Dogan, and Manant 2010). The common findings of the recent theoretical literature is that the trade-off between regulation and investment is still unsolved, that unregulated access price leads to foreclosure but implies better results in term of investment relatively to the regulation case (e.g., Foros 2004; Kotakorpi 2006; Sarmento and Brandão 2007) and that the requirement of full structural separation reduces the investment incentives of the incumbent (e.g., Sarmento and Brandào 2009; Sarmento 2011). The few works that consider the two kind of investment (incumbent investment in network upgrade versus the entrant investment in building their own facilities) show ambiguous effects of regulation on investment incentives (e.g., Vareda 2011; Manenti and Scialà 2013). Baranes, Ben Dkhil and Jebsi (2012) show that the trade-off between competition and investment can be only solved in the particular case where the integrated incumbent provides the high quality service and the regulator is able to set the access price at cost prior the investment decision.

Empirical works seem fail to give complete answer to the effects of regulation on telecom innovation. In particular, some studies find positive relationship between regulation and investment (e.g., Chang, Koski and Majumdar 2003 (the case of Europe); Alesina et al. 2005; London Economics 2006; Martha 2005; Grosso 2006; Djiofack-Zebaze and Keck 2009; Gruber and Koutroumpis 2012) while others find negative effects of regulation on telecom innovation (e.g., Chang, Koski and Majumdar 2003 (the case of USA); Distaso, Lupi, and Maneuti 2005; Waverman et al. 2007; Friederiszick, Grajek and Röller 2008; Bauer and Shim 2012; Grajek and Röller 2012; Baccache, Brourreau and Germain 2013; Nardatto, Valleti and Verboven 2014). However, few studies that use measurements of market competition rather than direct measures of regulatory reforms and consider non-linear specification show that this relationship is more complex: it is an inverted U relationship (see e.g., Heimeshoff 2007; Li 2008; Briglauer, Ecker and Gugler 2013).

The aim of the current empirical paper is to contribute to this debate by analyzing the individual, the joint and the global effects on the deployment of fixed broadband infrastructure technologies of the

[3] See ITU (2013) and Cowhey and Klimenko (2001).

following regulatory policy practices: the access price policies (Long Run Incremental Cost models, Full Distributed Cost, retail-minus, price ceiling, price cap, international benchmark), the separation policies (the strongest regulatory models of separation, vertical, functional, separation versus the lighter regulatory model , the accounting separation), the unbundling policies (the sub-loop access, the bit-stream, line sharing, full local loop unbundling), the transparency of access price, the transparency of access agreement, the privatization of incumbent operator and the independancy of regulatory authority.

We collected data information about these reforms from various sources including the regulatory data base of ITU and the officiel reports of NRAs, OECD and others. We constructed a panel composed from 107 developed and developing countries countries over the period from 2004 to 2011. Following the methodology of Zenhäeusern et al. (2007, 2012 a, 2012 b), we construct an indicator for each regulatory reforms to measure the individual impact of each one of this reform and aggregated measurements of regulatory policies in order to measure both the join and the global effect of regulation.

Following a robust econometric methodology, we conclude that we should take into account the following considerations: the non-linearity of the relationship between global or the join measurement of regulation and the broadband deployment (measured by the total broadband subscriptions), the heterogeneities across countries and years, the heteroskedastic and autocorrelated errors and the reverse causality between regulation and broadband penetration. Using appropriate tests, we show that the appropriate methods that permit to take into account these considerations are the following IV method & the GMM: *Two Stage Least Square with Fixed Effects (FE-2SLS*), *Two-Step Generalized Method of Moments with Fixed effect (FE-2S-GMM)* and *GMM Continuously Updated Estimator (FE-GMM-CUE)* robust to heteroskedastic and autocorrelated errors. Among that, the *FE-GMM-CUE* is the best because it has the properties to provide better results even in presence of weak instruments and insufficient number of observations (see Baum, Shaffer and Stillman 2003; Baum (2006); Baum, Shaffer and Stillman 2007 and Bascle 2008). As control variables, our models include the total population and the Gross Domestic Product (GDP).

As regards to the global issue of the regulation on broadband deployment, we obtain an original finding: *the relationship between regulation and broadband deployment is an inverted U shape in developed world while it takes a U form in developing countries*. These results mean that in the developing countries, a low level of regulation fosters broadband deployment while a restrictive regulatory policy impedes investment in broadband infrastructures. However, in developing countries, regulation undermines investment in broadband infrastructures. The differences in issues of regulation on telecom innovation between developed and developing countries may be due to the fact that in general, the existent fixed infrastructures in poor countries are not already sufficiently developed compared to those in more reach world.

Related previous empirical studies, Friederiszick, Grajek and Röller (2008), Grajek and Röller (2012) and Bauer and Shim (2012) are limited to investigate the issues of global effect of regulation in the case of developed world (European, OECD countries, USA, Japan), and find a strict negative impact of regulation on investment. Compared to our current empirical study, Friederiszick, Grajek and Röller (2008), Grajek and Röller (2012) do not take into account the non-linearity of the regulation-investment relationship while Bauer and Shim (2012) do not consider the heteroskedastic and autocorrelated errors, which are frequent problem in data. .

Concerning the individual and the join effects of the regulatory reforms, our results provide more support for the inverted U shape relationship. In particular, our findings show that requiring an extensive unbundling policy (sub-loop access) or the most stringent separation policies (operational, functional or structural separation) undermines broadband investment while a less intensive unbundling (full unbundling or bitstream) or a moderate separation policy (accounting separation) increases broadband deployment. As regards to the impact of access price regulation, our results show that the higher the intensity of the control of access price, the lower the broadband deployment. In particular, in the absence of access price regulation (no control), the broadband deployment is the highest. A moderate access pricing regime that offer certain access margin for incumbent firm such that the price cap or the retail minus regulation permits to reach better results in term of telecom innovation than adopting stringent access policies (the cost-based models such as LRIC or FDC). Most of these results about the issues of the individual reforms confirm both the results of previous empirical and theoretical works.

Our results on inverted U shape relationship between regulation and broadband deployment support the recent findings of researches on the linkage between competition and innovation. In particular, Heimeshoff (2007) and Briglauer, Ecker and Gugler (2013) find a closest result, an inverted U shape between *competition* and telecom investment by using measurement of competition (market share of incumbent firm, etc. This is not surprising. Indeed, the relationship between competition and regulation is positive because the integrality of regulatory reforms aim at reducing the market power and the discriminatory behaviors of the dominant operator (the incumbent), and therefore; promoting competition.

We find a further support for our results on inverted U shape between regulation and investment in broadband infrastructures for developed world in the theoretical and empirical economic literature that investigate the linkage between competition and innovation in a general context (see Aghion et al. 2005; Innui, Kawakami and Miyagawa 2008; Hashmi 2011; Aghion, Akcigit and Howitt 2013; Goettler and Gordon 2014). Aghion et al. (2005) and Aghion, Akcigit and Howitt (2013) interpret the overall effect (the *inverted U-shape*) as the "*composition effect"* of the two opposite traditional extreme effects of competition, *Escape* versus *Schumpeterian effects*. In particular, the increasing part of the U-curve that depicts the competition-innovation relationship represents the *escape effect of competition*, under which rivals are assumed escaping from competition by innovation to restore a part of their historical monopoly profits and therefore innovation is fostered for relatively low degree of competition. After a given certain level of competition (saturation point), the *Schumpeterian effect* will dominate because for relatively high degree of competition, rents earned from innovation are not sufficiently high to cover the costs of investment incurred by firms. Therefore, as regards to telecom context, our results can be interpreted as follows: for low degree of regulation (therefore low degree of competition), infrastructure owner escapes from competition by innovation (escape effect). After certain level of regulation, and thereby competition; infrastructure owners' profits earned from broadband deployment cannot cover the costs of investment because the high level of competition resulting from severe access regulation policy yields on decreasing retail sales of infrastructure owners by reducing final prices (the Schumpeterian effect).
We also find a support for our results of the U form between regulation and broadband deployment in developing countries in the findings of the theoretical growth model provided by Sacco and Schmutzier (2011) which demonstrates that this inverted U-shape relationship between competition and innovation is only conceivable when firm that invests in cost reduction is more efficient than its rivals. However, this relation is negative when firm that invests is less efficient than its competitors. Indeed, in the particular case of the telecom context, facts show that the incumbents in poor countries are generally less efficient than foreign entrants.

We show further that both the Gross Domestic product (the GDP) and the population size contribute to explain broadband deployment. In particular, we find that a 10% increase in GDP per capita (population size) leads to an average increase of broadband deployment by around 14% (12.1%). This result confirms most previous empirical studies.

The rest of this paper is organized as follows. In section 2, we provide the data description and the statistical analysis. In section 3, we present our empirical model. In section 4, we discuss our econometric methodologies and results. In section 5, we conclude and provide our policy recommendations.

2 Data and Statistique Analysis

Dataset used in this study is an annual unbalanced micro-panel composed from about 107 countries[4] covering a period of eight years from 2004 to 2011. Data are collected from various public sources including the databases of the International Telecommunication Union (ITU) (ITU World Telecommunication ICT indicators 2011[5] and ITU regulatory database 2012), the World Bank (WB) database, the OECD Communication Outlooks frm 2004 to 2011, and the Plaut Economics Regulation data constructed by Zenhäeusern et al. (2007, 2012 a, 2012 b)[6]. We also update data telecom performance from the web site of ITU and complete regulatory reform data from international, regional and national reports mainly come from ITU, OECD, European Commission (EC), European Investment Bank (EIB), European Mediterranean Regulators Group (EMRG), body of the European Regulators for Electronics Communications (BEREC) and regulatory authority web sites of different countries[7].

2.1 Variables

We classify variables used in this study into four groups: (1) The telecom performances indicator (the dependent variable) (2) the regulation reform measurements (the variables of interest) (3) the control and instrumental variables[8] and (4) dummies for various country classifications. Table 1 provides a summary of variable definitions sources and construction. The descriptive statistics for these variables are reported in the table A/ the Appendix.

Table 1: Definitions, sources and construction of the variables

Group	Variable	Definition	Source and construction
(1)	**Ln(fixed broadband subscriptions)**	The logarithm of the number of fixed broadband Internet subscriptions	ITU
	Accounting separation	Dummy that is equal to one if accounting separation is required and zero otherwise	Constructed by author following the scoring methodology of Zenhäeusern et al. (2007, 2012 a, 2012 b)using mainly information that come from ITU regulatory data set.Missing information are completed by author from reports of NRAs or international or regional organizations (OECD, EMRG, BEREC, EC, ITU, etc.)
	Functional separation	Dummy that is equal to one if functional, operational or structural separation are required and zero otherwise	
	Infrastructure sharing	Dummy that is equal to one if infrastructure sharing is required and zero otherwise	
	Full Local loop unbundling (full LLU)	Dummy that is equal to one if the full LLU is required and zero otherwise	
	Bitstream access	Dummy that is equal to one if the bitstream access is required and zero otherwise	
	Sub-loop access	Dummy that is equal to one if the sub-loop access is required and zero otherwise	
(2)	**Entry regulation**	Sum of entry regulation dummies (accounting separation, functional separation, full LLU, infrastructure sharing, Bitstream access and sub-loop access)	
	Interconnection regime	Indicator that take one of the following four possibly values : 0 if there is no control for access price, 0.5 if the access price regulation regime is moderated such as price ceiling, retail minus etc., 0.8 if the access price regulation is the FDC approach, 1 if the most restrictive access price regulation is required to incumbent such as LRIC, LRAIC	
	Transparency of interconnection agreements	Dummy that is equal to one if there is a requirement to publish interconnection agreements and zero otherwise	
	Transparency of interconnection price	Dummy that is equal to one if there is a requirement to publish interconnection price and zero otherwise	
	Market transparency	Sum of dummies of transparency of interconnection agreements and price	
	Status of SMP operator	Dummy that is equal to one if the fixed-line operator (incumbent) is 100% state owned and zero otherwise	

[4] In particular, two countries (Haîti & Jamaîca) are not included in estimation results because we do not have completed data for these countries.

[5] We are thankful to ITU for sending this database.

[6] We are grateful to Patrick Zenhäeusern for sending these data.

[7] Further details about our data source can be obtained by addressing a request to the author.

[8] Instrumental variables are a variables used in estimations. Further details about these variables are provided in the next section of this current study.

		Regulatory autonomous decision	Dummy that is equal to one if there is an independent regulatory body and zero otherwise.	
		Overall reform	Sum of all regulatory dummies listed above and the interconnection regime indicator	
		Overall reform index	Overall reform/11 (11 is the number of regulation reform considered)	
		Entry reform index	Entry regulation/6 (the number of entry regulation reforms)	
(3)		Ln(GDPpc)	Per capita gross domestic product	WB
		Ln(Population)	Population size	
		Internet users (per 100 people)	Percentage of Internet users	
		Regulatory Quality	Score that proxy the government ability to require policies that promote private sector	WB See Kaufmann, Kraay and Mastruzzi (2010)
		Voice and Accountability	Score the degree of freedom of expression, association and media	
(4)	1	High income: Non OECD (WB)	Dummy that is equal to one if the country in a given year is classed as high income (developed) country by the WB and it is not a member of OECD, and zero otherwise.	WB & OECD classifications
		High income: OECD (WB)	Dummy that is equal to one if the country in a given year is classed as high income (developed) country by the WB and it is a member of OECD, and zero otherwise.	
		Europe & Central Asia (WB)	Dummy that is equal to one if the country in ECA region is classed as developing country by the WB and zero otherwise.	
		Middle East & North Africa (WB)	Dummy that is equal to one if the country in MENA region is classed as developing country by the WB and zero otherwise.	
		Latin America & Caribbean (WB)	Dummy that is equal to one if the country in LAC region is classed as developing country by the WB and zero otherwise.	
		East Asia & Pacific (WB)	Dummy that is equal to one if the country in EAP region is classed as developing country by the WB and zero otherwise.	
		Sub-Saharan Africa (WB)	Dummy that is equal to one if the country in SSA region is classed as developing country by the WB and zero otherwise.	
		South Asia (WB)	Dummy that is equal to one if the country in SA region is classed as developing country by the WB and zero otherwise.	
	2	OPEP	Dummy that is equal to one if the country in a given year is member of OPEP and zero otherwise.	OPEP classification
	3	Non- OECD	Dummy that is equal to one if the country in a given year is not a member of OECD and zero otherwise.	OECD classification
	4	Non-EU countries	Dummy that is equal to one if the country in a given year is not a member of EU and zero otherwise.	EU classification
	5	Developing countries (IMF)	Dummy that is equal to one if the country in a given year is Considered as developing country by the IMF and zero otherwise.	IMF classification
	6	Developing countries (UN)	Dummy that is equal to one if the country in a given year is Considered as developing country by the UN and zero otherwise.	UN classification
	7	High income (WB)	Dummy that is equal to one if the country in a given year is Considered as high income country by the WB and zero otherwise.	WB classification
		Upper-Middle income (WB)	Dummy that is equal to one if the country in a given year is Considered as upper-middle income country by the WB and zero otherwise.	
		Low-Middle-income (WB)	Dummy that is equal to one if the country in a given year is Considered as low-middle income country by the WB and zero otherwise.	
		Low-income (WB)	Dummy that is equal to one if the country in a given year is Considered as low income country by the WB and zero otherwise.	

2.1 Comparative statistical analysis

In this paragraph, we provide a comparative statistical analysis for the evolution of broadband subscriptions (the dependent variable) and the overall and the entry regulation measurements (the main variables of interest) across the world using appropriate graphs and considering the international and regional country classifications.

2.1.1 The evolution of fixed broadband subscription across the world

The *fixed (wired) broadband Internet subscriptions* measures total Internet connection subscriptions at high downstream speeds (i.e. superior or equal to 256 kbit/s) via fixed Internet technologies (cable modem, Digital Subscriber Line (DSL), fiber-to-the home/building, etc.)[9]. Otherwise, this indicator measures total demand for high[10] quality Internet connection (retail service) addressed to all operators (incumbent and entrants) in a given country during a given year. Recently, most studies consider this indicator as the best proxy of innovation in telecom industry (see for e.g., Wallsten (2006), Badran, EL Sherbini and Ragab (2007), Waverman et al. (2007), Cambini and Jiang (2009), Bouckaert, Dijk and Verboven (2010), Bauer and Shim (2012) and Gruber and Koutroumpis (2012)). The explanations of the popularity of this measure are the following: (1) This measure is easy to obtain by regulatory national authorities in comparison with other measures (specially the investment in telecom services[11]). (2) This indicator is well relevant to explain investment in high quality infrastructures (fiber-to-home, etc.).

Line charts provided in figure1 illustrates evolution of the total broadband subscriptions per 100 people in different countries of our dataset over the period from 2004 to 2011. Basing on both the WB & the OECD country classifications, high income countries are dived into categories: the OECD and the NON-OECD countries while developing countries are grouped by region.

Graphs show significant differences between groups of countries, ranging from below 0.8% in Sub-Saharan Africa to 5.17% in Middle East and North Africa, 6.37% in South Asia, 11.62% in East Asia and Pacific, 13.82% in Latin America and Caribbean, and 71.61% in high income countries. Line charts also depict that penetration broadband rate in developing countries has increased slowly than in high income countries between 2004 and 2011.In general, it seems from this that penetration rate is positively affected by income level. Horizontal bar charts (Figure A/Appendix)[12], that present penetration rates from 2004 to 2011 respectively for high, upper-middle, low-middle and low income countries, are more convenient to illustrate the strong link between income level and broadband penetration rate. In particular, fixed broadband subscriptions per 100 people is below 0.7% in low income countries and 8% in low middle income countries while rates reach more than 22% in some upper-middle income countries and 40% in some high-income countries. However, some exceptions appear clearly when considering bar charts for high and upper-middle income countries. In particular, penetration rates are low for some high income countries such that Saudi Arabia (below 5.62%), Oman (below 1.85%), Brunei Darussalam (below 5.72%) while rates are high for some upper-middle income countries such that Lithuania (more than 22.13%), Latvia (about 20.39%), Bulgaria (roughly 16.44%) and Belarus (around 21.939%). This implies that income level is not the sole determinant of broadband deployment.

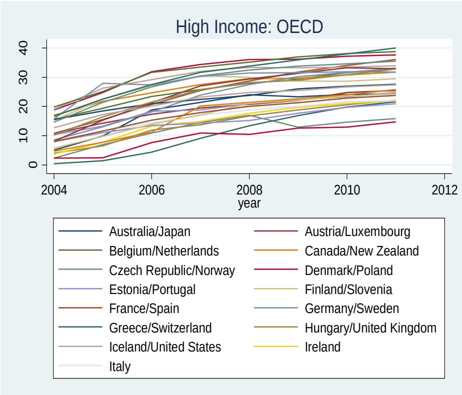
[9] This definition is re-formulated using the note for this indicator (n°I4213TFB) given by ITU World Telecommunication ICT indicators 2011.

[10] Broadband Internet is considered as substitute for traditional access service (dial-up access) because it permit to consumers to access to high quality retail service (i.e. higher speeds and other features such that facilitating of the use) (Sutherland 2007).

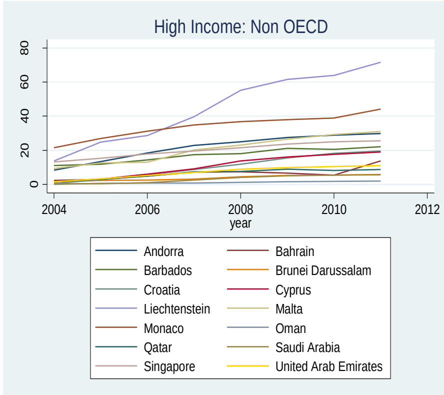
[11] Generally, the infrastructure owners (in most cases, the incumbent, the operator with Significant Market Power (SMP) do not give its real cost of investment.

[12] For space, certain figures and tables are reported in the Appendices.

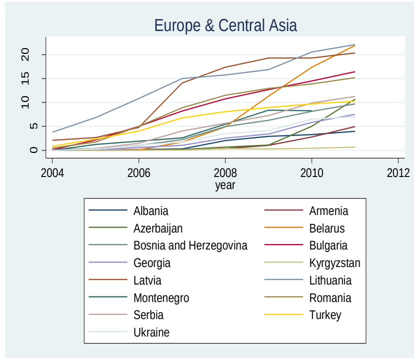
Graph 1



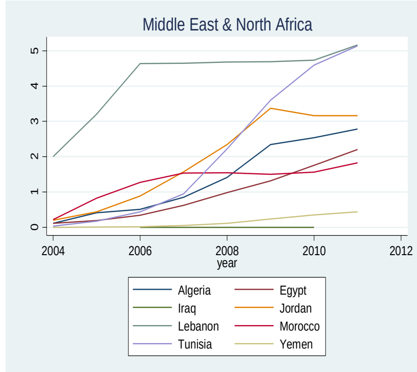
Graph 2



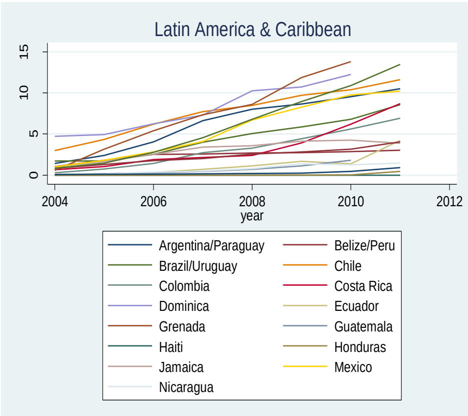
Graph 3



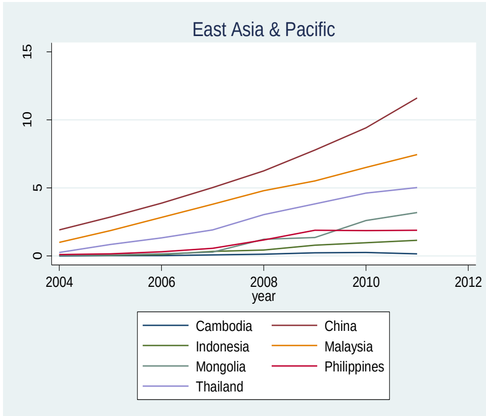
Graph 4



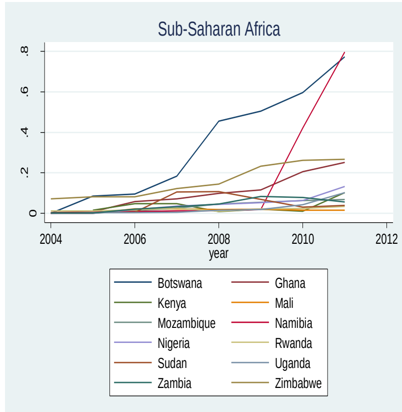
Graph 5



Graph 6



Graph 7



Graph 8

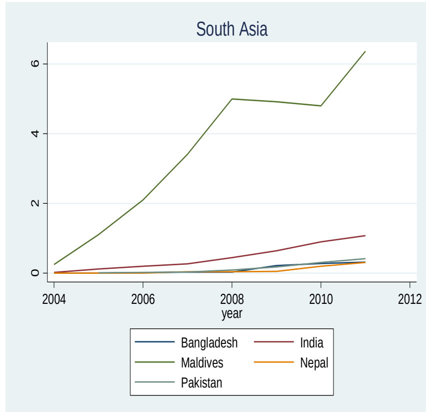


Figure 1: Fixed Broadband Subscriptions per 100 people over 2004-2011
High-income countries (grouped as OECD & non-OECD)/ other countries (grouped by region)
Source: the author.

2.1.2 The measurements and the evolution of the regulation

There are two ways to enter the telecom markets: (1) *the service-based entry*, in which entrants provide their end-user services using the existent facilities of the historical integrated monopoly (the incumbent), and (2) *the facility based entry*, in which entrants provide their services using their own network infrastructures. As the facilities-based competition is not generally easy to introduce because infrastructure duplications are costly and sometimes not economically efficient[13], regulators in majority of countries are turn on ensuring services-based competition through requiring some obligations to incumbent in order to limit the scope of its market power and thereby, prevent its discriminatory behaviors and therefore, ensure and promote competition. In particular, Entrants are permitted to share the incumbent's facilities through requiring access technical policies (certain forms of unbundling or infrastructure sharing) against a regulated access price.

2.1.2.1 The classification and the measurements of the regulatory reforms:

Access regulation policies including various access pricing, unbundling and separation policies can be ranged from the weakest to the strongest regulation required to the dominant operator (the incumbent). A strongest regulation results in more competition since it reduces the market power and discriminatory behavior of the dominant operator and vice versa.

- The cost-based pricing models such as the long Run Incremental costs (LRIC) which is based on the current costs of infrastructure building and the fully distributed cost (FDC), which is based on the historical infrastructure costs, do not permit to incumbent to earn sufficient mark up over the marginal cost of access service provision and therefore, these access pricing models should permit more competition compared to the non-cost based access pricing policies such as the retail minus, price cap and international benchmark which permit to incumbent to earn non negative profits from its access activities. Figure 2 provides a classification of access pricing policies from the weakest to strongest basing on Zenhäeusern et al. (2012 a, 2012 b) and Mihevc (2010).

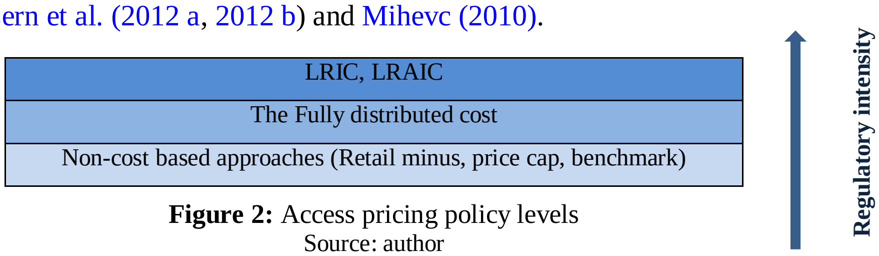


Figure 2: Access pricing policy levels
Source: author

- A Severe unbundling requirement (the sub-loop unbundling) that leads to more technical obligations to incumbent against more advantages for entrant relatively to more moderate forms of unbundling (full local loop unbundling, line sharing, bitstream) permits to increase competition. Following Wallsten 2006 and OECD (2003 a), we classify the unbundling policy with respect to intensity of regulation required to incumbent as illustrated in figure 3:

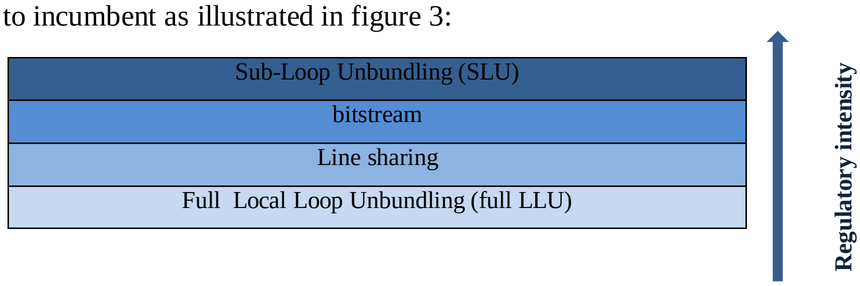


Figure 3: Unbundling policy levels
Source: author

[13] See, Laffont and Tirole 2000.

- Partner and Lawyer (2011); Cave (2006) ; Malcolm (2008); OECD (2003 b, 2006, 2011 a) classify separation policies as follows: The full structural separation, which consists to prohibit the incumbent to provide end-users services, is considered the strongest form of separation required to incumbent because it reduces sensibly its market power by limiting the scope of its activity in providing access to rivals. The forms of separations (functional or operational separation) that require to incumbent firm to separate its retail activities from the wholesale business (providing access services to rivals) by creating divisions in its own integrated company are considered a moderate form of separation compared to the full structural. The lowest form of separation is the requirement of separation of accounts (accounting separation). Figure 4 summarizes this classification.

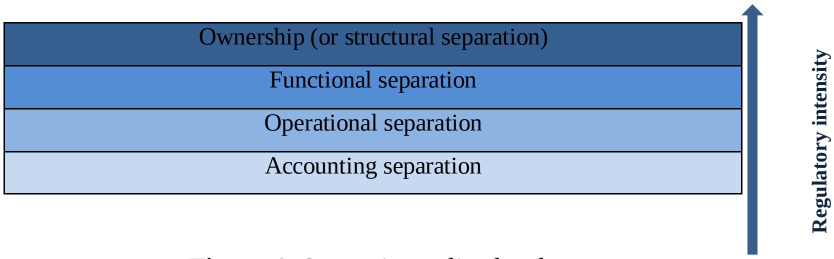


Figure 4: Separation policy levels
Source: author

Although the differences in the definitions of these various forms of separation, regulatory reports usually confuse the following models of separation: structural, functional & operational. Therefore, we use a sole binary variable (that we call *functional separation*) to measure the requirement of one of these three form of separation in a given country to a given year (see table 1).

We compute the other measurements of regulatory reforms used in this study as descripted in table 1. The aggregated measurements proxy the intensity of regulation in a given country for a given year: the higher the value of these measures, the higher the intensity of regulation and vice versa. These measures therefore can be seen as indirect measurements of intensity of competition in telecom market since these regulatory reforms are required to incumbent in order to reduce their market power and discriminatory behaviors against their rivals.

This current study consider both the aggregated measures (*overall regulation*, *interconnection market transparency* and *entry regulation*) and the disaggregated measures (*accounting separation* , *functional separation, infrastructure sharing*, *full LLU, bitstream*, *sub-loop*, *interconnection regime*, *transparency of interconnection agreements*, *transparency of Interconnection price, status Incumbent* and *regulatory autonomous decision of regulation*, which are binary variables that take a value of 1 of the corresponding reform is required; see table 1). This is another important contribution of this study relatively to earlier studies. The previous studies have limited to study the issues of some individuals reforms: impact of access price regulation (e.g., Chang, Koski and Majumdar 2003; Distaso, Lupi and Maneuti 2005; Waverman et al. 2007; Seo and Shin 2011), the unbundling policies issues (e.g., Grosso 2006; Wallsten 2006; Baccache, Brourreau and Gaudin 2013; Nardatto, Valleti and Verboven 2014), or the separation policies effects (e.g., Viani 2006; Bruno 2012). At our knowledge, only the studies of Friederiszick, Grajek and Röller (2008), Grajek and Röller (2012) and Bauer and Shim (2012) have investigated the global effects of regulation using the index computed by Zenhäeusern et al. (2007, 2012 a, 2012 b) but they do not investigate the individual impact of each reform. Further, in our knowledge, the integrality of these studies have studied the impacts of regulation on investment in telecommunication infrastructures in the case of developed countries (European or OECD countries) but not the case of developing countries, except the studies of Martha (2005) and Gruber and Koutroumpis (2012) which only investigate the effects of unbundling policies in the case of both developed and developing world. According to our researches, there is no study that investigates the impacts of separation and access price regulation in developing countries.

2.1.2.2 The evolution of regulatory intensity across countries over the world

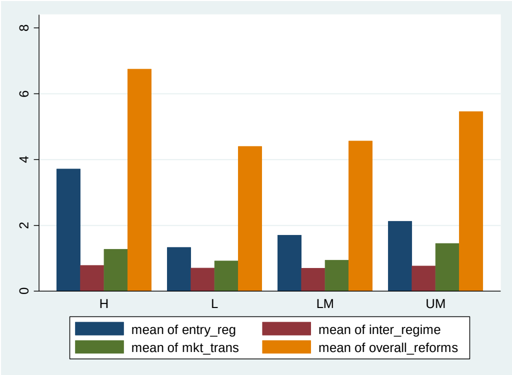
In this paragraph, we compare and discuss using some graphs the evolution of the regulation intensity across countries included in our panel. It appears from the first bar charts (see Graph1/ Figure 5) that the regulation intensity is on average increasing in income level. Precisely, the high income countries have on average the highest regulation intensity. They are followed in the second rang by the upper-middle income countries, then the low-middle income and finally by the low income countries. This result is not surprising. In fact, implementation of regulation reforms such that unbundling, accounting and others types of separation and cost-based pricing or LRIC models is costly. [14]

The second bar charts (Graph2/ Figure 5) show that high income countries that are members of OECD are on average the highest regulation intensity. This result is also illustrated by bar charts in graph3. This outcome is consistent with the role of OECD in promoting telecom regulation policies to ensure competition and to promote broadband roll out. This may be also due to the recent extensive telecom regulatory frameworks of European Union since the majority of countries members of OECD are also members of EU. Graph4 illustrates this issue. However, it seems from Graph 5 that be member of OPEC has no effect in terms of telecom regulation. In fact, the role of OPEC is limited to strategies that concerns exportation of petrol. OPEC countries such Saudi Arabia and Oman have high income but both low telecom performances and low regulation intensity. This implies that in addition to income level, other factors may have an important role in development of telecom industry. These factors can be summarized in development level of a given country. However, as noted above in paragraph 2.1 the World Bank classifies high income countries level as developed. This is not the cases of other world organizations such that IMF and UN. Graphs 6 and 7 in Figure 5 supports this intuition that the development level of a country, that can incorporate factors related to human resources such that the level of education and political system in a given country that may be also important determinants of regulatory policy introduction. According to OECD (2005), high quality staff of regulators ensures high telecom quality regulation. In addition, political environment in a given country (political stability, absence of Violence/Terrorism, global regulatory quality, rule of Law, control of Corruption, freedom of expression, association and media etc.) guarantees the dependency of regulatory authorities, that is necessary to achieve telecom regulation goals consisting on improvement of market transparency, effective competition and high quality of telecom services[15]. For example, we think that the high regulation intensity in MENA countries (see Graph 4/ Figure B/Appendix) is due to political choice that permits high degree of open (especially relations with Europe). The best illustration is Tunisia that introduced unbundling policies, accounting separation and cost-oriented models for interconnection charges since 2008. The staff of regulation may also explain the high regulation intensity in Tunisia (see Graphs 2 and 3 in Figure C/Appendix, which illustrate evolution of regulation measures by country).

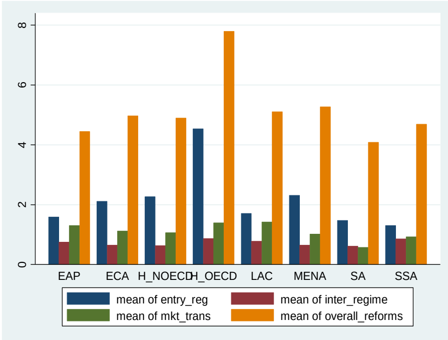
[14] For example, introducing accounting separation reform implies "adaptation costs for existent accounting systems"[14]. Also implementing operational, functional or structural separation implies costs of creation of new divisions, units or subsidiaries (costs of construction, costs of introduction of new financial, management, information and legal systems, costs of recruitment of new staffs, costs of buying of new equipment (software or hardware). For example, applying the full structural separation in 2003 to incumbent firm (Telstra) in Australia implies important fixed costs that are estimated to reach about USD 1.9 billion and annual additional costs of about USD 76 million[14] and costs of functional separation of British Telecom in United Kingdom reached GBP 70 million in 2006 (Malcolm 2008). The implementation of the full LLU also implies costs such as those related to the maintenance of the copper pair, security, installations of equipment, etc. (OECD 2003 a). Introducing LRIC models also require estimating costs incurred by the incumbent and collecting data about demand for the telecom services, which implies important information costs for regulator. In general, application of the cost-based access pricing is very costly (Malcolm 2008).

[15] Several empirical studies consider that political variables are important determinants of regulation in telecom industry. We cite, for example, Djiofack-Zebaze and Keck (2009), Friederiszick, Grajek and Röller (2008), Grajek and Röller (2012), Gruber and Koutroumpis (2012) and Bauer and Shim (2012). We will discuss later this relation between global political system and telecom regulation later.

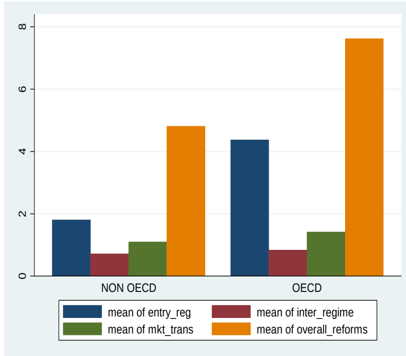
Graph 1: World Bank classification
(by level of income)



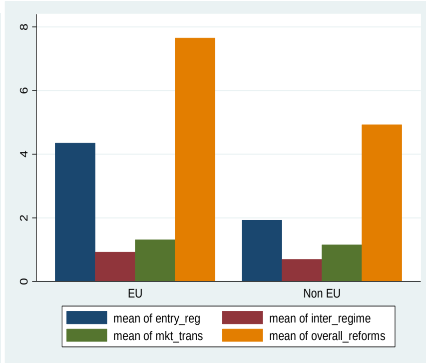
Graph 2: World Bank classification :
High-income countries (grouped as OECD and non-OECD)/ other countries (grouped by region))



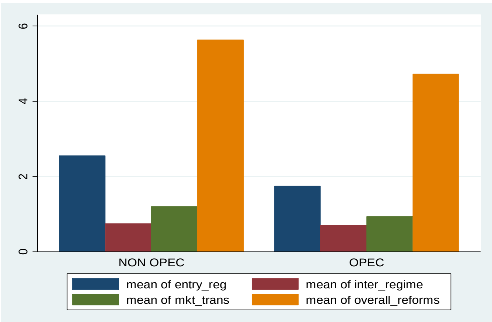
Graph 3: Classification OECD
(OECD/ NON OECD)



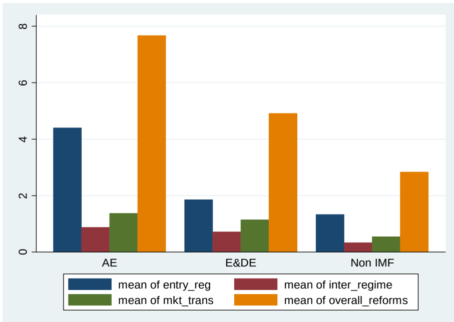
Graph 4: Classification EU/NON EU



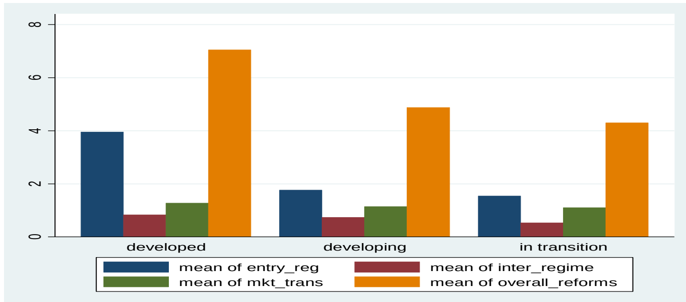
Graph 5: Classification OPEC/NON OPEC countries



Graph 6: Classification IMF



Graph7: Classification UN



Notes: ECA: Europe and Central Asia ; MENA: Middle East and North Africa; H_NOECD: High income: non OECD countries; H_OECD: High income: OECD countries; LAC: Latin America and Caribbean; SA: South Asia; SSA Sub-Saharan Africa: countries; EAP: East Asia and Pacific; H: High income countries, L: low income countries, LM: Low-middle income, UM: Upper-middle income. EU: countries members of European Union.

Figure 5: Comparison between means of regulation measures over the world across different country classifications

Source: the author

3 The empirical benchmark model

Following previous empirical studies, telecom performances are a function of regulation reform measurements and a set of control variables:

$$\textbf{\textit{Telecom Performance Indicator}} = f(\textbf{\textit{Regulation Reform measurements}}, \textbf{\textit{vector of control variables}})$$

Furthermore, our specifications account for the following considerations:

(1) The cross-country effect:

Baltagi (2005) notes that Panel Data have the advantage to control for individual heterogeneity and "*give more informative data, more variability, less collinearity among the variables, more degrees of freedom and more efficiency*". Ignoring individual heterogeneity often leads to biased results[16]. Therefore, we include dummies for countries to take into account individual fixed effects.

(2) Temporal effect:

Telecom performance indicators vary over time for each country. Then, we introduce year dummy variables to take into account the presence of time effects.

(3) Linearity of the relation:

Several empirical papers show that the relationship between regulation reforms and telecom performances is non-linear. Therefore, we introduce a non-linear component. In line with previous empirical studies such that Heimeshoff (2007) and Bauer and Shim (2012), we assume that this non-linear component corresponds to the squared of the regulation reform measure.

(4) Dynamic nature of telecom investment (broadband deployment)

In line with number of empirical studies such that Heimeshoff (2007), Friederiszick, Grajek and Röller (2008), Bouckaert, Dijk and Verboven (2010), Bauer and Shim (2012) and Baccache, Brourreau and Gaudin (2013), we also consider the long term (dynamic) effect of investment in telecom infrastructure (broadband deployment proxy by broadband penetration) by including lagged dependent variable in the model.

In consequence, our *empirical benchmark* model takes finally the following general form:

$$\mathrm{TPI_{it}} = \alpha_0 + \alpha \mathrm{RM_{it}} + \emptyset \mathrm{TPI_{it-1}} + \beta \mathrm{C_{it}} + \gamma_t + \delta_i + \varepsilon_{it} \qquad (4.1)$$

$\boldsymbol{TPI_{it}}$ is the telecom performance indicator in country *i* at year *t* expressed in natural logarithm[17]. It represents a proxy of telecom performances, which are the fixed broadband subscriptions. RM_{it} is a vector of regulation measurements. This may correspond to one or more regulation reform measurements (*interconnection regime*, *accounting separation*, *functional separation*, *infrastructure sharing*, *full LLU*, *bitstream access*, *sub-loop access*, *transparency of interconnection agreements*, *transparency of interconnection price*) or one or more aggregate regulation measurements (*overall regulation*, *entry regulation*, *transparency of interconnection terms*) plus square terms (square of these aggregate measurements or square of *interconnection regime*). $\mathrm{TPI_{it-1}}$ is the lagged dependent variable (by one year). $\mathrm{C_{it}}$ is a vector of control variables that capture the impact of other determinants of telecom performance, which are the *per capita GDP* and the *population size* expressed in natural logarithm. The error terms γ_t, δ_i and ε_{it} capture respectively time fixed effects (fixed effect for each year *t*), country fixed effects (fixed effect for each country *i*[18] and variation of telecom performances that is not explicitly included in the model. α is the intercept. The vector of parameters $\boldsymbol{\alpha}$ measures the impact of regulation reforms on telecom performance. The vector of parameters β measures the contribution of control variables in explication of telecom performance variation.

[16] See Baltagi (2005, pp.18-19).

[17] The choice of the natural logarithm transformations for our continuous variables is to prevent possibly stationary series and normality data problems. Friederiszick, Grajek and Röller (2008)and Grajek and Röller (2012) make this transformation for the same purpose.

[18] γ_t*, and* δ_i are dumy variables taking value 1 for respectively year *t* and country *i*. We drop one of country-specific effects (e.g., δ_1) and one of time-specific effects (e.g., γ_1), to avoid perfect collinearity (Greene 2002, see p.291 and p.118).

4 The Econometric methodology

Empirical studies reach opposite conclusions about regulation-telecom performances relationship. Econometric techniques may be one of the major factor that affect results and conclusions. Therefore, we use usual estimators including the simple Ordinary Least Squares (OLS) and the fixed effects (FE) estimator as well as the Instrumental Variables (IV) and Generalized Methods of Moments (GMM) that overcome several problems that characterize data. In particular, we proceed as follows. After checking and discussing the possibly multi-collinearity problem between the explanatory variables used in this study, we begin by applying series of regressions using Ordinary Least Squares (OLS) method. Performing a number of tests[19], we conclude that we should take into account fixed effects and control for heteroskedasticity and autocorrelation of error terms. We deal with these problems by using robust fixed effects models with cluster on countries (robust FE with clusters). Analyzing results obtained by both OLS and robust FE with clusters, we conclude that these estimators not yield consistent estimates[20]. According to Baltagi (2005), both OLS and FE yield biased results in the case of dynamic specifications. Further, these usual estimators do not control for the reverse causality between regulation and telecom performance, omitted explanatory variables and errors of measurements of variables. A number of empirical works (e.g., Alesina et al. 2005; Distaso, Lupi, and Maneuti 2005; Waverman et al. 2007; Friederiszick, Grajek and Röller 2008; Li 2008; Djiofack-Zebaze and Keck 2009; Bauer and Shim 2012; Grajek and Röller 2012; Gruber and Koutroumpis 2012; Baccache, Bourreau, and Gaudin 2013; Briglauer, Ecker, and Gugler 2013; Nardatto, Valleti and Verboven 2014) point out on the existence of two types of problems when analyzing the impact of regulation (or competition) on telecom innovation :

(1) *The reverse or simultaneous causality between regulation and innovation*: In fact, telecom performances including broadband deployment or subscriptions, affect regulatory decisions. In a given country, the regulator decides appropriate regulation reforms following the characteristic of the existent national telecom markets (level of competition, level of investment, prices ...). For example, in the United States where telecom markets show sufficient competition, the strategic of regulator seem seeking to reduce reforms required to significant market power operators (incumbent firm) over time in order to encourage more investments in NGNs. In contrast, in Europe where the facts (prices, technology subscriptions, market shares..) show that traditional telecom monopoly has yet a significant market power, the regulators focus on promoting service-based competition by requiring more reforms to incumbent firms.

(2) *The omitted regulatory variables*: In fact, the collect of precise and complete information about telecom regulatory reforms and the construction of relevant measurements for these qualitative variables are delicate. In particular, we ignore certain regulatory reforms given the non-availability of information. Further, we use generally law texts which only give information about the date of the requirement of the regulation reforms rather than the year of its effective implementation or its application.

The most appropriate methods to overcome these two problems in our case are the Instrumental Variables (IV) and Generalized Methods of Moments (GMM) methods. In particular, we use Two Stage Least Square (2SLS), Two Step Generalized Methods of Moments (2S-GMM) and GMM Continuously Updated Estimator (FE-GMM-CUE))[21].

Furthermore, All our estimations with 2SLS, 2S-GMM or GMM-CUE method control for:

(1) Fixed effects FE (country and year dummies): Our motivation behind the choice to apply these methods with fixed effects instead to first difference is the characteristic of our sample, which is

[19] These tests are: Breusch-Pagan Lagrange Multiplier test (B-PLM test), Hausman test, the “modified Wald test for group-wise heteroskedasticity”, Wooldridge tests for serial correlation (see the diagram reported in the Appendix).

[20] For space, we do not report the OLS and the robust Fixed estimations. We are limited here to provide the robust results obtained using the IV & GMM methods.

[21] All tests, applications, description concerning these methods are accomplished in this paper basing on the works of Baum, Shaffer and Stillman (2003); Baum (2006); Baum, Shaffer and Stillman (2007) and Bascle (2008).

strongly heterogenous as it includes both developed and developing countries [22]. In addition, as shown later, the inclusion of year effects permit to capture the evolution of broadband deployment over period 2004-2011. Further, Hausman tests applied to IV regressions reject its null that differences in coefficients of fixed and random IV estimators are not systematic meaning that fixed effect IV estimator is preferred to random effect IV estimator.

(2) Heteroskedasticity and autocorrelation robust to heteroskedasticity and autocorrelation[23]: Indeed, the Pagan-Hall IV heteroskedasticity test, formulated by Pagan and Hall (1983)[24] , rejects its null hypothesis that the errors are homoskedastic and the Arrellano-Bond tests for autocorrelation Arellano and Bond (1991) reject its null hypothesis that there is no first-order correlation between errors.

Basing on the econometric literature review and developments of Baum, Shaffer and Stillman (2003); Baum (2006); Baum, Shaffer and Stillman (2007) and Bascle (2008), we summarize the differences between these estimators as follows:

▫ The 2SLS estimates are obtained by applying simple OLS on equation (4.2). If the standard assumptions on covariance matrix of error term of main equation (i.e. absence of serial correlation and homoskedasticity erros) hold, the 2SLS estimates are more efficient than 2S-GMM estimates, which are obtained with respect the violation of these assumptions. In particular, the 2SLS is none other than a special case of GMM estimator, that is considered the most efficient estimator if equations (3.2) are over-identified, the total number of observation NT is important enough (more than 700 observations), the errors are heteroskedastic and autocorrelated, there is a lagged dependent variable, and instruments are strong.

▫The GMM-CUE is a GMM applied to Limited Information Maximum Likelihood (LIML) estimator, which is an IV method that is based on Maximum Likehood (ML) function instead to basing on minimizing the sum of squares of errors terms (for example OLS method). The GMM-CUE estimator is shown better than 2SLS and 2S-GMM estimators if the instruments are week and the number of observations is low enough.

In general, the consistency of the estimations with IV & GMM depends on the goodness of the instruments[25] used for the endogenous regressors (the regulatory measurements). Therefore, we proceed as follows to ensure the consistency of our results:

Firstly, we select the possibly instruments by referring to related literature and econometric theory. We use three kinds of instruments, *(1) the lagged endogenous regressors* which are usually valid instruments (see, Cameron and Trivedi 2005, p.743). (2) the *Political and institutional indicators:* Related literature (i.e., Djiofack-Zebaze and Keck 2009; Friederiszick, Grajek, and Röller 2008, Cambini and Rondi 2009; Grajek and Röller 2012; Gruber and Koutroumpis 2012; Bauer and Shim 2012) suggest that political and institutional characteristics of a given country such that political orientation and ideology of political parties (right to left), independence of regulatory authorities and political systems (parliament, presidential,..etc.) are the key determinants of telecom regulation. In line with this empirical literature, we use the Worldwide Governance indicators, which come from World Bank data base[26] (3) the *Internet users per 100 people:* Reverse causality from market telecom

[22] We are also try the difference GMM but tests show that this method is not appropriate. This may be due to the extreme heterogeneities of our panel.

[23] Results for IV/GMM methods with clusters on countries are similar to those obtained with bw (2). For space, we do not report it. For further details about our methodology see the diagram reported in the Appendix.

[24] Cited by Baum, Shaffer and Stillman (2003); Baum (2006); Baum, Shaffer and Stillman (2007) and Bascle (2008)

[25] The instruments used must satisfy two necessary conditions:

(1) **The relevance condition**: Each one of instrument must be correlated with the endogenous regressors. A high (low) correlation indicates that the instrument is "strong" ("week") while no correlation implies that the instrument is "irrelevant". In general, the consistency of estimates obtained using the IV techniques depend on instruments 'strength. The higher the instruments' strength, the "higher" the consistency of the IV estimator.

(2) **The exogeneity condition** (also called "orthogonality condition"): the e vector of instruments must be not correlated with the vector of error terms of the model.

[26] Data available at: <http://data.worldbank.org/data-catalog/worldwide-governance-indicators>. These indicators are constructed by Kaufmann, Kraay, & Mastruzzi (For more details, see Kaufmann , Kraay , and Mastruzzi 2010). These indicators correspond to codes of replies on the quality of government perceptions according to selected citizen, number of enterprise, and experts. In particular, this dataset is composed from six political and institutional indicators: 1- *Political stability and absence of violence/ terrorism*, , 2-*Government Effectiveness* that measures the perceptions regarding the public service quality and degree of respect of commitment to policies

performance to regulation implies that some indicators of telecom performance, such as the *Internet users per 100 people*, may be a good determinant of the regulation policies decided by the NRA (relevance condition). However, to ensure exogeneity condition, this variable must be not correlated with unobserved factors (error terms of the model) that explain broadband deployment. Diagnostic tests show that the "*Internet users per 100 people"* is a valid instrument for regulatory measurements in certain specifications (see next paragraph).

5 The Estimation Results and robustness checks

In this paragraph, we start by presenting our estimation results. Then, we interpret and compare these results with results of previous empirical researches. Finally, we check the robustness of these results by analyzing the results of the first and second stage diagnostics (i.e. the post estimation diagnostic tests).

5.1 Presentation of results

The aim of this study is to examine the role of regulation in driving or delaying innovation in telecom industry across the world. To this end, we fitted two sets of regressions.

- The first one, which incorporates four regressions denoted A, B, C and D, has as goal to analyze both individual and global effects of regulation on telecom innovation. Regressions A, B, C and D differ on the regulation measurements considered. In regression A, we focus on the impacts of overall regulation while in B we are interested in the effects of each one of the following aggregated measurements: *entry-regulation, market transparency and interconnection regime*. The regressions C and D provide the specific impacts of the individual reforms. In particular, in regression C, we study the particular effects of each one of the following reforms: *accounting separation, functional separation, Sub-loop access, Transparency of interconnection Agreements, Transparency of interconnection price, Status of SMP operator, Regulatory autonomous decision. In regression D, we add the rest of the reforms considered in this study (i.e., Infrastructure sharing, Full local loop Unbundling, Bitstream access, interconnection regime, square of interconnection regime)*. Table 2 summarizes, for each one of these regressions, results of estimations and post-estimation diagnostic tests
- The second set of regressions that includes three models denoted I, II and III, examines haw can vary the global effect of regulation when isolating one or more groups of countries, each one has a common characteristic such as income level or appurtenance or not to OECD. In regression I, we interact the *overall regulation* and its square to dummy for country classification by appurtenance or not to OECD. In regression II, the overall regulation and its square are interacted to dummy that takes 1 if country is classified by the World Bank as high income country. In regression III, we interact the overall regulation and its square to dummies for different country classifications by income levels (low, low middle, upper middle incomes). Table 3 summarizes results of estimations and post-estimation diagnostic tests for each one of these regressions.

implemented by the government , 3- *Rule of Low*, which proxy the perceptions regarding the applications of lows. 4- *Control of corruption*, which measures perceptions regarding the degree of control of corruption 5- *Regulation quality*, which proxy the perceptions of government ability to implement policies that encourage development of private sector. 6- *Voice and Accountability*, which proxy perceptions regarding degree of freedom of expression, associations and media. However, in this study, we do not use all these six above governance indicators. In particular, only Voice and Accountability and Regulation quality are used. Indeed, post estimation diagnostic tests show that only Voice and Accountability and Regulation quality are valid as instruments for certain specifications (see next paragraph). Further, we cannot use simultaneously these four governance indicators (Government Effectiveness, Rule of Low, Control of corruption and Regulation quality) as instruments for regulatory measurements in a same regression because, as shown in the following table, there is strong multicollinearity (VIF>10) between these four governance indicators:

Table 2: Internet broadband subscriptions and regulation (individual & global impacts of regulatory reforms)

IV/GMM estimators robust to heteroskedasticity & and autocorrelation (Kernel=Bartlett; bandwith=2) with FE (country & year dummies **included)**
Dependent variable: Ln (fixed broadband subscriptions)

Model	**(A)**			**(B)**			**(C)**			**(D)**		
Estimation methods	**IV-2SLS**	**2S-GMM**	**GMM-CUE**	**IV-2SLS**	**2S-GMM**	**GMM-CUE**	**IV-2SLS**	**2S-GMM**	**GMM -CUE**	**IV-2SLS**	**IV-2SLS**	**IV-2SLS**
Ln(fixed broadband subscriptions) $_{t-1}$	0.2499*** (0.0379)	0.2501*** (0.0379)	0.2501*** (0.0379)	0.2591*** (0.0399)	0.252*** (0.0386)	0.251*** (0.038)	0.227*** (0.0321)	0.227*** (0.032)	0.2269*** (0.0320)	0.2231*** (0.0344)	0.2265*** (0.0342)	0.2252*** (0.0342)
Overall reform	0.4571*** (0.1503)	0.4655*** (0.1477)	0.4657*** (0.1481)									
Square of overall reform	-0.0372*** (0.0112)	-0.0378*** (0.0111)	-0.0378*** (0.0111)									
Entry regulation				0.6202*** (0.142)	0.614*** (0.1413)	0.614*** (0.1409)						
Square of Entry regulation				-0.1151*** (0.0236)	-0.112*** (0.0231)	-0.112*** (0.2304)						
Interconnection regime				-0.9511^{+} (0.5924)	-0.9923* (0.5884)	-0.994* (0.588)				-0.6204 (0.8190)	-0.6861 (0.8103)	-0.6416 (8589)
Square of Interconnection regime				0.9507^{+} (0.5822)	1.033* (0.573)	1.036* (0.573)				0.7246 (0.7025)	0.9129 (0.6824)	0.8842 (0.7096)
Transparency of interconnection terms				-1.3127*** (0.3641)	-1.3125*** (0.3608)	-1.314*** (0.359)						
Square of Transparency of inter. Terms				0.5575*** (0.1632)	0.5587*** (0.1614)	0.559*** (0.160)						
Accounting separation							0.297* (0.18)	0.306* (0.178)	0.307* (0.178)	0.3116* (0.1878)	0.3545* (0.1842)	0.3490* (0.1839)
Functional separation							-0.391** (0.158)	-0.394** (0.158)	-0.394** (0.158)	-0.5295*** (0.2020)	-0.4996** (0.1995)	-0.4963** (0.2058)
Infrastructure sharing										-0.1062 (0.2264)	-0.1949 (0.2209)	-0.2234 (0.2248)
Full local loop Unbundling										0.4467 (0.3441)	0.4573 (0.3397)	0.4422 (0.3513)
Bitstream access										-0.2556 (0.2264)	-0.1941 (0.2206)	-0.1489 (0.2279)
Sub-loop access							-0.443** (0.218)	-0.447** (0.217)	-0.447** (0.217)	-0.5220* (0.2825)	-0.6007** (0.2774)	-0.6237** (0.2877)
Transparency of interconnection Agreements							0.325* (0.197)	0.3302* (0.197)	0.3309* (0.1975)	0.3626^{+} (0.2244)	0.4163^{+} (0.2216)	0.438* (0.2234)
Transparency of interconnection price							-0.626*** (0.226)	-0.626*** (0.226)	-0.626*** (0.226)	-0.5866** (0.2465)	-0.6418*** (0.2440)	-0.6671*** (0.2455)
Status of SMP operator										0.0684 (0.3404)	0.1224 (0.3373)	0.1216 (0.3434)

Regulatory autonomous decision										0.3578 (0.3784)	0.2755 (0.3556)	0.2704 (0.3614)
Ln(GDP_{pc})	1.7967*** (0.4082)	1.8127*** (0.4048)	1.8134*** (0.4063)	1.3098*** (0.4124)	1.281*** (0.408)	1.273*** (0.403)	1.459*** (0.382)	1.436*** (0.377)	1.436*** (0.376)	1.3273*** (0.4197)	1.2663*** (0.4120)	1.2831*** (0.4104)
Ln(Population)	0.8158* (0.4303)	0.8168* (0.4303)	0.8168* (0.4329)	1.1058** (0.4737)	1.163** (0.468)	1.163** (0.467)	1.877*** (0.461)	1.869*** (0.460)	1.870*** (0.4594)	1.9524*** (0.5440)	2.036*** (0.5389)	2.087*** (0.3614)
Number of observations	676	676	676	671	671	671	669	669	669	664	664	664
Number of countries	104	104	104	103	103	103	104	104	104	103	103	103
Second stage diagnostic												
R^2	0.7098	0.6808	0.6798	0.693	0.693	0.6928	0.6914	0.691	0.691	0.6850	0.6761	0.6743
Overall F statistic	71.2***	35.84***	34.47***	50.79***	52.1***	52.03***	51.08***	51.26***	51.18***	34.19***	35.28***	33.5***
Endogenous regressors	Overall reform, square of Overall reform			Entry regulation; Square of Entry regulation; Interconnection regime; Square of Interconnection; Transparency of interconnection terms; Square of transparency of interconnection terms			Accounting separation; Functional separation; Sub-loop access; Transparency of interconnection agreements Transparency of interconnection price			Interconnection regime;Square of interconnection regime ; Accounting separation;Functional separation; Infrastructure sharing;Full Local loop unbundling; Bitstream access; Sub-loop access;; Transparency of interconnection agreet. Transparency of interconnection price;Status of SMP operator;Regulatory autonomous decision		
Excluded instruments	lagged Overall reform, lagged square of overall reform, lagged Voice and Accountability			One –year lags of endogenous regressors, Voice and Accountability; Regulation quality.			One –year lags of endogenous regressors Internet users (per 100 people);			One-year lags of endogenous regressors ;One-year lag of Regulatory quality; One-year lag of Voice and Accountability; Internet users (per 100 people);		
<u>**First-stage diagnostics & post-estimation tests: (1)**</u>												
R^2	0.5662 , 0.5640			0.5904; 0.5739; 0.4309; 0.4458;0.326; 0.305			0.4338; 0.4583; 0.428; 0.272; 0.3178			0.4193, 0.4304, 0.4555, 0.4662, 0.4315, 0.4261, 0.4709, 0.4465, 0.2849, 0.329, 0.3585, 0.2768		
Overall F statistic	**37.25*** , 36.31*****			**23.3***; 20.6***; 10.3***; 11.3***; 7.9***; 7.6*****			**11.5***;11.2***; 5.06***; 7.2***;7.79*** **			**6.78***, 7.3***, 9.34***,7.89***,7.71***,3.87***, 7.57***, 3.35***,5.2***, 5.82***, 1.95***,1.48*****		
F test of excluded instruments	59.75*** , 58.85***			14.9***; 20.6***; 18.2***; 20.4***; 10.1***; 10.8***			20.8***; 12.9***; 8.4***; 12.6***; 6.6***			8.53***, 9.15***, 12.6***,7.9***, 7.09***,4.97***, 8.79***, 5.15***, 6.40***, 4.15***, 2.75***, 2.00**		
AP Chi-sq	**25.53*** , 22.81*****			**28.68***; 29.72***; 10.01**; 21.55***; 7.8**; 8.3****			**119.0***;79.3***;37.8***;47.7***;36.2*** **			**8.37*, 18.4***, 117.4***, 73.6***, 66.5***, 37.7***, 66.4***, 36.27***,46.08***, 35.29***, 29.76***, 19.03*****		
Angrist-Pischke multivariate F test of excluded instruments	12.50*** , 11.17***			9.27***; 9.61***; 3.24**; 6.97***; 2.55*; 2.71**			57.9***; 38.6***; 18.4***; 23.2***; 17.6***			2.0*,4.4***,28.1***,17.6***,15.9***,9.02***,15.89***,8.68***, 11.03***,8.45***,7.12***,4.55***		
S-Y critical values for single endogenous regressor (2SLS & 2S-GMM/CUE-GMM)												
5% maximal bias	13.91			20.25/N.A.			19.28/N.A.			21.23/N.A.		
10% maximal bias	N.A.			9.08/N.A.			N.A.			10.27/N.A.		

20% maximal bias	N.A.	6.46/N.A.	N.A.	6.71/N.A.
30% maximal bias	N.A.	5.39/N.A.	N.A.	5.34/N.A.
10% maximal size	19.93/8.68	22.3/6.46	19.93/ 8.68	24.58/5.44
15% maximal size	11.59/5.33	12.83 /4.36	11.59/5.33	13.96/3.87
20% maximal size	8.75/4.42	9.54/3.69	8.75/ 4.42	10.26/3.3
25% maximal size	7.25/3.92	7.8/3.32	7.25/3.92	8.31/2.98
Underidentification test: Kleibergen-Paap rk LM statistic	39.837***	44.34***	30.443***	32.159***
Overidentification test of all instruments: Hansen J statistic (p-value) 2SLS & 2S-GMM/CUE-GMM	0.093(0.761)/0.092(0.7613)	0.728(0.6947) /0.725(0.6959)	0.131(0.7176)/0.131(0.7176)	3.318 (0.3451)/ 3.053(0.3836)
Weak identification test : Cragg-Donald Wald F static	106.207	18.966	18.764	4.97
Kleibergen-Paap rk Wald : F static	50.335	8.797	6.513	2.236
IV LM redundancy tests of specified excluded instrument: (2)	42.285***, 47.421***, 6.093***	57.08***; 48.82***; 12.914**; 20.215***; 36.392***; 38.496***; 14.11**; 5.775. 21.683	58.871***; 22.866***; 18.724***; 33.051***; 29.257***; 8.726+	25.887**, 28.949***, 53.224***, 25.973***, 54.067***, 47.421***, 29.229***, 34.523***,35.395***, 22.295***, 9.617, 16.22, 23.018** 12.207,58.245***
Weak-instrument-robust inference tests: 1/Anderson-Rubin Wald tests: F-test	3.91***	4.7***	3.43***	2.17*** 34.06***
2/Stock-Wright LM S test: Chi-sq	10.99**	28.48***	14.8**	
Endogeneity test Chi-sq statistic (p-value)	6.839**	22. 45***	13.311**	21.81**

Notes: In the first part of this table, we provide the results of estimations of each regression using respectively the IV-2SLS, 2S-GMM and GMM-CUE with fixed effects robust to heteroskedastic and autocorrelated erros. The statistical significance levels are presented by stars as follows: *** (significant at 1% level), ** (significant at 5% level), * (significant at 10% level), + (significant at 15% level). The robust standard errors are reported in parenthesis below the estimate coefficients. The second stage diagnostics of each regression (see section 4.4.1.1) show that all models are well specified and globally significant. In particular, the high level of R^2 show the importance of the contribution of the explanatory variables to explain the dependent variable while the high significance level of the overall F statics shows that all the coefficients of regressors are different than zero. In the second part of the table, for each regression, we provide the list of the endogenous regressors as well as the excluded instruments used in the first stage estimations. In the rest of the table, we provide the first stage diagnostics and the post estimation tests (see Box 3 for a description of these tests). The values of R^2, the overall F statics and the F statics of excluded instruments, the AP Chi-statics, the AP F-statics correspond respectively to the first stage estimations of the list of endogenous regressors in the order followed in the table. For specification C, we also compute redundancy tests for a set of instruments for further checks about validity of our instruments: (1) the set of instruments are Internet users (per 100 people); One-year lag of Regulatory quality & One-year Lag of Voice and Accountability), we obtain LM statics =59.808*** (p-value=0.0076). (2) The instruments are : one year-lags of "Interconnection regime" & "Square of interconnection regime", we obtain LM statics 58.245*** (p-value= 0.0001) (3) The instruments are one year-lags of "Transparency of interconnection price" & "Regulatory autonomous decision", we find 43.763*** (p-value= 0.0081).

Table 3: Internet broadband subscriptions and regulation (impacts across country classifications)
IV/GMM estimators robust to heteroskedasticity & and autocorrelation (Kernel=Bartlett; bandwith=2) with FE (country & year dummies included)

Dependent variable: Ln (fixed broadband subscriptions)

Model	**(I)**			**(II)**			**(III)**		
Estimation methods	**2SLS**	**2step-GMM**	**CUE-GMM**	**2SLS**	**2step-GMM**	**CUE-GMM**	**2SLS**	**2step-GMM**	**CUE-GMM**
Ln(fixed broadband subscriptions) $_{t-1}$	0.225*** (0.0331)	0.225*** (0.0331)	0.225*** (0.0331)	0.222*** (0.0339)	0.225*** (0.0339)	0.231*** (0.034)	0.206*** (0.206)	0.205*** (0.035)	0.199*** (0.035)
Overall reform	0.442*** (0.146)	0.461*** (0.143)	0.461*** (0.143)	0.3* (0.165)	0.294* (0.160)	0.264* (0.159)	0.455*** (0.149)	0.484*** (0.144)	0.492*** (0.144)
Square of Overall reform	-0.044*** (0.0108)	-0.045*** (0.010)	-0.045*** (0.010)	-0.021+ (0.013)	-0.022* (0.013)	-0.019+ (0.013)	-0.043*** (0.011)	-0.043*** (0.01)	-0.043*** (0.01)
Non OECD *Overall reform	-0.104 (0.0843)	-0.103 (0.084)	-0.103 (0.084)						
Non OECD*square of Overall reform	0.0204** (0.009)	0.0202** (0.009)	0.0202** (0.009)						
H *Overall reform				0.187** (0.087)	0.157* (0.084)	0.194** (0.084)			
H*square of Overall reform				-0.024** (0.01)	-0.022** (0.01)	-0.025** (0.01)			
UM *Overall reform							-0.057 (0.094)	-0.0166 (0.091)	-0.014 (0.09)
UM*square of Overall reform							0.009 (0.011)	0.004 (0.011)	0.04 (0.011)
LM *Overall reform							-0.296** (0.13)	-0.266** (0.126)	-0.276** (0.125)
LM*square of Overall reform							0.035** (0.016)	0.031** (0.015)	0.032** (0.015)
L *Overall reform							-0.683** (0.3)	-0.7203** (0.308)	-0.75** (0.3)
L*square of Overall reform							0.112* (0057)	0.1106* (0.057)	0.118** (0.057)
Ln(GDP$_{pc}$)	1.414*** (0.367)	1.397*** (0.360)	1.397*** (0.360)	1.473*** (0.378)	1.358*** (0.369)	1.481*** (0.373)	1.158*** (0.381)	1.158*** (0.377)	1.158*** (0.369)
Ln(Population)	0.854** (0.410)	0.836** (0.409)	0.836** (0.411)	0.941*** (0.429)	0.928** (0.428)	1.038** (0.435)	0.851** (0.407)	0.851** (0.405)	0.851** (0.403)
Number of observations	669	669	669	669	669	669	664	664	664
Number of countries	104	104	104	104	104	104	103	103	103
Second stage diagnostic									
R^2	0.7092	0.7085	0.7084	0.7062	0.7061	0.7063	0.7068	0.7072	0.7038

Overall F statistic	59.69***	63.66***	63.41***	58.52***	62.61***	63.79***	50.72***	51.63***	50.78***
Endogenous regressors	Overall reform; square of overall reform, Non OECD *overall reform, Non OECD *square of Overall reform			Overall reform; square of overall reform, H *overall reform, H *square of Overall reform			Overall reform; square of overall reform; UM *overall reform; UM *square of Overall reform; LM *overall reform; LM *square of Overall reform; L *overall reform, L *square of Overall reform		
Excluded instruments	one year lags of endogenous regressors; one year lags of Voice and Accountability; Internet users (per 100 people)			one year lags of endogenous regressors; one year lags of Voice and Accountability ; Internet users (per 100 people); H* one year lags of Voice and Accountability			one year lags of endogenous regressors; one year lags of Voice and Accountability ; one year lags of regulatory quality; Internet users (per 100 people)		
<u>**First-stage diagnostics & post-estimation tests: (1)**</u> **R^2**	0.5706; 0.5694; 0.4775; 0.5224			0.5682; 0.5674; 0.6196;0.6031			0.5711; 0.5702; 0.4637; 0.4669; 0.3975; 0.3513; 0.2655; 0.1494;		
Overall F statistic	30.40***; 30.5***; 23.26***; 20.33***			29.27***;29.06***; 23.93***; 24.52***			24.99***;23.26***; 11.83***.; 11.93***; 7.99***; 5.92*** 1.86**;		
F test of excluded instruments	31.98***; 33.8***; 24.96***; 28.22***			27.7***; 30.12***; 31.47***; 36.56***			17.3***;; 18.1***;15.4***;16.49***; 11.2***; 8.3***;2.3***; 1.7*		
AP Chi-sq	20.95***; 12.14***; 27.67**; 31.06***;			16.82***; 13.24***; 14.99**; 12.04***			21.18***;18.86***;7.32+; 7.04+;7.71+; 4.71; 4.38; 2.81		
Angrist-Pischke multivariate F test of excluded instruments	6.80***; 3.94***; 8.98***; 10.08***;			4.09***; 3.22**; 3.64*** ; 2.92**			5.11***; 4.55***; 1.76+; 1.7+ 1.86+; 1.14; 1.06; 0.68;		
S-Y critical values for single endogenous regressor (2SLS & 2S-GMM/CUE-GMM) 5% maximal bias 10% maximal bias 20% maximal bias 30% maximal bias 10% maximal size 15% maximal size 20% maximal size 25% maximal size	19.28/N.A. 9.08/N.A. 6.46/N.A. 5.39/N.A. 22.3/6.46 12.83/4.36 9.54/3.69 7.8/3.32			19.86/N.A. 10.27/N.A. 6.71/N.A. 5.34/N.A. 24.58/5.44 13.96/3.87 10.26/3.30 8.31/2.98			20.90/N.A. 10.27/N.A. 6.71N.A. 5.34/N.A. 24.58/5.44 13.96/3.87 10.26/3.3 8.31/2.98		
Underidentification test: Kleibergen-Paap rk LM statistic	47***			47.929***			11.265**		
Overidentification test of all instruments: Hansen J statistic (p-value) 2SLS & 2S-GMM/CUE-GMM	0.388(0.8238) /0.386(0.824)			5.298(0.1513) /5.526 (0.1371)			4.527(0.2098) /4.528(0.2098)		
Weak identification test : Cragg-Donald Wald F static	46.219			41.039			4.527		
Kleibergen-Paap rk Wald : F static	22.454			21.752			0.956		
IV LM redundancy tests of specified instrument: (2)	17.871***; 22.277***; 10.039**; 18.697***; 8.529*; 10.803**			35.647***; 37.542***; 35.488**; 52.572***; 18.064***; 6.932+; 13.506**			35.818***; 20.88***; 44.36***; 51.81***; 55.823***; 49.368***; 35.81***; 20.88***; 8.765; 15.98**; 24.1***		
Weak-instrument-robust inference tests: 1/Anderson-Rubin Wald tests: F-test 2/Stock-Wright LM S test: Chi-sq	4.85*** 23.51***			5.05*** 22.66***			3.22*** 26.66**		
Endogeneity test Chi-sq statistic (p-value)	14.105***			14.201***			16.292**		

Notes: Statistical significance levels: *** (1% level), ** (5% level), * (10% level), + (15% level). We also report robust standard errors in parenthesis. (1) We report first stage diagnostic for respectively each endogenous regressors considered (2) See the list of excluded instruments in the middle of the table. See Box N°3 for description of tests applied and reported in this table.

5.2 Estimation results: implications and comparisons

The exam of the first parts of tables 2 and 3 show that results not differ systematically across regressions and estimation methods used in this study. We can summarize the main finding in the following points:

The dynamic adjustment process of the broadband deployment

The coefficients of the lagged dependent variables (Ln(fixed broadband subscriptions) $_{t-1}$), are highly significant (at 1% level) and positive across all our specifications, which is consistent with expectations. The magnitudes of these coefficients are quite similar across different regressions performed in this study (they are between about 0.19 and 0.25. Results imply that the investment in broadband has high persistent time effects. Broadband deployment follows therefore a long term adjustment process. The positive sign can be interpreted as follows: the higher the stock of broadband investment across previous years, the higher its current variation. More precisely, according to our estimations, a 10% increase in the current stock of broadband infrastructures lead to an average increase by around 2% in the next year. This result on dynamic adjustment process of telecom infrastructure deployment is consistent with related empirical finding that consider dynamic specifications (e.g., Li and Xu 2004; Alesina et al.2005; Heimeshoff 2007; Friederiszick, Grajek, and Röller 2008 ; Li 2008; Djiofack-Zebaze and Keck 2009; Bouckaert, Dijk, and Verboven 2010; Bauer and Shim 2012; Grajek and Röller 2012; Gruber and Koutroumpis 2012; Baccache, Brourreau and Gaudin, 2013; Nardatto, Valleti and Verboven 2014).

The important contribution of the national income on broadband deployment

The coefficients of logarithm of per capita GDP are highly significant (at 1% level) and positive across all our regressions. These results are also consistent with expectations. Their magnitudes vary from 1.15 to 1.82. We can interpret this finding as follows: a 10% increase in GDP per capita leads to an average increase of broadband deployment by around 14% . This result shows the importance of contribution of national income in increasing broadband deployment in countries across the world. The integrality of various related empirical studies consider that income measured by GDP is the main determinant of telecom investment and share common result on strong positive relationship between income and telecom innovation.

The Population size is an important determinant of broadband deployment

The coefficients of logarithm of population size are positive but their significance level and magnitude respectively vary from 0.81 to 2.08 across different specifications considered. These results are consistent with expectations. This shows that the population is also an important determinant of broadband deployment. The higher the population, the higher the broadband subscriptions (cetirus paribus) and therefore the broadband deployment. Precisely, a 10% increase in population size leads to an average increase of broadband deployment by around 12.1%. This result on strong positive correlation between population size and broadband deployment confirms the finding of the previous empirical related studies (e.g., Martha 2005; Bauer and Shim 2012; Gruber and Koutroumpis 2012).

The impact of the common unobserved macro-economic factors on the broadband deployment

Results show high statistical significance for all trends of year dummies (see Table B in the Appendix). Specially, trend for year 2005 is positive and very high (more than 1.31) meaning that the common unobserved favorable macro-economic factors have contributed significantly to accelerate broadband adoption by a minimum average of about 131% relatively to 2004. However, since 2006, year trends became negative and decreasing (in absolute value). This may be due to financial crises of 2006, the United States American financial bubble of 2006 that propagates to overall economics across the world since 2006[27].

The Impacts of the regulatory reforms on broadband deployment

Turning now on impacts of our variables of interest (aggregated and disaggregated regulatory measurements), results lead to three conclusions:

The regulation and broadband deployment: an inverted U relationship

The Overall regulation and entry regulation coefficients are highly significant (at 1% levels) and positive while the coefficients of both squares of overall regulation and entry regulation measures are highly significant (at 1% level) and negative (see regressions A and B / table 2), suggesting that the regulation-broadband penetration relationship is an inverted-U-shape. A direct mathematical interpretation of this result is the following: regulation is positively correlated with broadband penetration for low level of regulation and negatively correlated with broadband penetration for high level of regulation. This result confirms the previous empirical works that use measurements of competition (such that market shares of providers or number of operators) to measure regulation (e.g., Heimeshoff 2007; Li 2008; Briglauer, Ecker and Gugler2013) which support both the theoretical and empirical finding on inverted U form relationship between competition and innovation demonstrated by the economic researches (see, Aghion et al. 2005; Innui, Kawakami and Miyagawa 2008, Hashmi 2011; Aghion, Akcigit and Howitt 2013; Goettler and Gordon 2014). In fact, our aggregated measurements of telecom reforms reflect the intensity of regulation required to incumbent firm in order to avoid its anti-competitive behaviors and thereby promote service-based competition. We can explain our result on inverted-U relationship basing on the interpretation of Aghion et al. (2005) and Aghion, Akcigit, and Howitt (2013) as follows: for low degree of regulation (therefore low degree of competition) , infrastructure owner escapes from competition by innovation (escape effect). After certain level of regulation and thereby competition, infrastructure owners' profits earned from broadband deployment cannot cover the costs of investment because the high level of competition resulting from severe access regulation policy yields on decreasing retail sales of infrastructure owners by reducing final prices (the Schumpeterian effect). However, our finding contrasts with the results of Friederiszick, Grajek, and Röller (2008), Grajek and Röller (2012) and Bauer and Shim (2012) that show a strict negative impact of regulation on investment. However, we have some reproaches to these studies. Firstly, Friederiszick, Grajek, and Röller (2008) and Grajek and Röller (2012) do not consider a non-linear model to estimate the relationship between regulation and investment. Secondly, the closest study to our one, Bauer and Shim (2012) use limit number of observations (232 observations versus about 671 in our study) they not control for possibly problems of heteroskedastic and autocorrelated erros .

[27] See Chang (2011) for a review of the issues of the "financial crisis 2007-2010".

The Individual and the join impacts of regulatory reforms

Regarding the impacts of the access price regime and the square of access price regime, the transparency of access terms and the square of transparency of access terms (see model B / Table 2), we obtain the following results. The coefficient of the access price regime is significant at 15% level but negative and the square of access price regime has significant and positive coefficient. These mean that the intensity of access pricing regulation is negatively correlated with broadband adoption: the lower the access price, the higher the broadband penetration and vice versa. Otherwise, requiring severe access price policy (e.g. LRIC model) undermines investment while less intense access price policy (e.g. price cap, retail minus,) or no control at all spurs broadband deployment. This confirms the result of Bauer and Shim (2012) and many other empirical works. Precisely, Chang, Koski and Majundar (2003) find a negative impact of access price on the share in fiber optic or digital lines in USA. Distaso, Lupi and Maneuti (2005) and Waverman et al. (2007) show that the access price (the price of local loop unbundling) affects negatively the broadband deployment measured by broadband subscriptions in Europe. Seo and Shin (2011) find that price cap regime has ameliorated the productivity of the USA telecom firms. Further, the negative and the highly significant coefficient of transparency of access terms show the negative effect of this obligation required to incumbent on broadband adoption. These results gives more explanation of the inverted-U-shaped relationship between broadband penetration and overall regulation: more extensive regulation such that requiring severe access regulation to incumbent operator such that a strong regulation of access price (cost based models such that FDC to LRIC method) and imposing the principle of transparency of access terms, or imposing to incumbent firm high intensity of entry regulation measure reduce broadband investment while a less severe regulation that consists to require to incumbent a moderate access price policy such that a price cap regime or to impose a limit number of entry regulation measurements seems necessary to foster investment in broadband networks.

These results are confirmed again by considering more disaggregated regulation reform measures (see models C & D/ Table 2). Indeed, our general conception about the regulation-broadband adoption relationship is that a less extensive regulation stimulates investment while more extensive regulation impedes investment remain unchanged. Results show that Accounting separation, the weakest degree of separation, is positively associated with broadband penetration across different models considered while the more stringent degree of separation, the functional separation, negatively affects broadband penetration. For the unbundling policies, results show that only the coefficient of the most extensive unbundling policies, the sub-loop access is statistically significant (at 10% and 5%) level and has a negative sign, which confirms the results of Wallsten (2006).

The impact of the overall regulation across countries classifications

Regarding the impact of the overall regulation on broadband adoption across countries classifications, we interact the overall regulation and its square with dummies for OECD countries (specification I), high income countries (specification II) and the Upper middle, the Low middle and the Low income countries (specification III) (see table 3).

Results of the FE-2SLS, the FE-2step-GMM and the FE-CUE-GMM estimations can be summarized in the two following points:

o The coefficient of the overall regulation measure is highly significant (at 1% level) and positive for OECD countries but negative, although not significant for non OECD countries while the coefficient of square regulation reform is highly significant (at 1% level) and negative for OECD countries but positive and statistically significant (at 5% level) for non OECD countries. Therefore, in OECD countries, the relationship between broadband penetration and regulation is an inverted-U-shaped while it is ambiguous in the rest of the world.

o Specifications II and III provide more clarification and precision to identify this relationship across the world. Precisely results show that in high income countries, this relationship is an inverted U-shaped. In the rest of the world, this relationship takes U form meaning that access regulation has strict negative impact on broadband deployment. Indeed, coefficients of overall regulation are significant and negative while their respective squares are positive and significant, except those interacted with dummy of the middle income countries which have same correspond signs but not significant. This non-significance may be due to problem of week instruments for specification III (see the next paragraph). We explain this last problem by the important numbers of the endogenous regressors considered in this last specification.

Our explanation to these last results is the following:

o The non-significance of the coefficient of overall regulation for non-OECD countries casts doubts on the goodness of this classification (OECD/Non-OECD) to understand the impacts of regulation on broadband penetration across countries in the world. Precisely, this classification only permits to identify this relationship for OECD countries but not for the rest of the world. In particular, For OECD countries, this relationship can be described as follows: a less extensive regulatory policy stimulates broadband adoption while more extensive policy undermines investment in broadband networks.

o However, it seems that the World Bank classification by income levels is more convenient to clarify the regulation-broadband penetration relationship across the world. Considering the World Bank classifications, there are two cases. In high income countries, as noted above, the inverted U-form of the curve that depicts regulation-broadband penetration relationship implies that a less extensive regulatory policy stimulates broadband adoption while more extensive policy undermines investment in broadband networks. However, regarding the rest of the world, it seems that in these countries, the relationship between regulation and broadband deployment takes U-form which means that regulation affects negatively broadband investment. This may be due to the fact that in general the existent fixed broadband infrastructures in poor countries are not already sufficiently developed compared to those in more reach world and therefore regulation may discourage facility-based entry, which seems the sole solution to build immediately advanced network infrastructures in these countries.

5.3 Robustness of the results: post-estimation diagnostic tests

Results of diagnostic tests (see the last part of tables 2 and 3) permit the following conclusions for each specification considered:

▫ Chi-squared statistic of endogeneity test applied to the subset of endogenous regressors considered is highly significant (at 1% and 5% levels), which implies that the use of 2SLS/GMM methods as estimators is appropriate.

- The overall F-statistics of first stage equations are highly significant (at 1% and 5% levels), which implies that the instruments used to explain the endogenous regressor are jointly significant. However, there are some exceptions. In particular, in specification III/ Table 3, the F-statistic (equal to 1.33) of first-stage equation that explains the endogenous regressor, which is the interacted term of square of overall regulation with the low-income countries dummies, is not significant.

- F-tests of excluded instruments reject its null hypothesis (F statistics are significant) which implies that the excluded instruments used to explain the endogenous regressor considered are relevant (except some exceptions in specification III/ Table 3).

- Both statistics (F and Chi-squared) of the Angrist-Pistache tests are significant, which confirm the previous results that the excluded instruments used are relevant and appropriate to identify the endogenous regressors considered. (except specification III/3, for which the Angrist-Pistache tests fails to reject its null hypothesis for some first-stage equations).

- The results of under-identification tests are consistent with the conclusion of valididy of our instruments. Indeed, the Kleibergen-Paap rk LM statistics are highly significant (at 1% level), which indicates that the rank condition of matrix of coefficients of first-stage equations is satisfied and therefore the excluded instruments are relevant to explain the variation of the endogenous regressors.

- The significant results of different redundancy tests applied to one or more specific instruments also confirm this finding on validity of our instruments.

- The Hansen J test fails to reject its null hypothesis (high p-value of Hansen J statistic) which implies that the endogeneity conditions of instruments are also satisfied.

- The weak-instrument-robust inference tests reject their null hypothesis (statistics F and Chi-squared of Anderson-Rubin Wald test and chi-squared of Stock-Wright LM S test are significant) indicating that the instruments are valid and the endogenous regressors considered are jointly significant in main equation.

- Despite that the weak identification tests of Stock and Yogo (2005) are not appropriate to study the strength of our instruments in our case (see Box N°3) because the critical values computed by Stock and Yogo (2005) require that both homoskedasticitic and non- autocorrelated errors assumptions are satisfied, the most considered appropriate statistics, which is Kleibergen-Paap Wald rk F statistics, are superior to critical values computed by Stock and Yogo (2005) . Nevertheless, to ensure more consistency for our estimation results, we always perform, for each specification, a GMM-CUE estimator which is considered the less sensible IV method to weak identification problem as noted above. The estimation results of this last method are very similar to results obtained using 2SLS or 2S-GMM, which confirm again the consistency of our estimation results.

To summarize, post-estimation diagnostic tests permit to conclude that our estimations are consistent . Indeed, our choice to estimate regulation-broadband penetration relationship using 2SLS/GMM methods with fixed effects and robust errors is appropriate, instruments used for each regression are valid and endogenous regressors are jointly significant in main equations.

6. Conclusion and Policy recommandations

In this study, we have investigated the individual, the joint and the global effects on the broadband deployment of the following regulatory reforms: access pricing regimes, unbundling and separation policies & the obligation of transparency of access price and aggreements, using an heterogeneous panel including both developed and developing countries over the period of 2004-2011and following a robust empirical methodology.

Results suggest that the relationship between regulation and broadband deployment is an inverted U shape in reach countries while it takes U form in more poor countries. This means that in the first class of countries, a low level of access regulation (leading to low competition intensity) spurs innovation in telecom industry while a high level of access regulation (leading to more competition) undermines investment in broadband infrastructures. In particular, no control to a less intense access price regulation that consists to apply moderate access pricing regime that offer certain access margin for incumbent firm such that price cap or retail minus permits to drive innovation while the stringent access policy which consists to require cost-based models (LRIC, FDC) impedes broadband deployment. In the same, requiring extensive unbundling policy (sub-loop access) as well as extensive separation policies (operational, functional or structural separation) undermines broadband investment. However, in more poor countries access regulation has a strict negative impact on telecom innovation. In fact, in these countries, the existent infrastructure networks are not sufficiently developed compared to those in reach countries.

Our analysis provides the following main policy recommendations for telecom industry development:

- Regulators in poor countries must immediately encourage facility-based entry by reducing or even stopping access regulation requirements imposed to incumbent firms (in general the owners of network infrastructure, the major suppliers) in order to promote foreign investments in telecommunications fixed infrastructures.

- Regulators should follow moderate regulatory policy in developed world in order to promote broadband deployment.

Appendix

Table A. Descriptive statistics

Group		Variable	Mean (overall)	Std.Dev	Min	Max	Observations
(1)		**Ln(fixed broadband subscriptions)**	10.986	4.722	-6.158	18.868	N = 806/ n = 106/ T-bar =7.603
(2)		Functional separation	.0782	.268	0	1	N = 856/ n = 107/ T = 8
		Infrastructure sharing	.6091	.488	0	1	N = 856/ n =107/ T = 8
		Full Local loop unbundling	.537	.498	0	1	N = 856/ n =107/ T = 8
		Bitstream access	.424	.494	0	1	N = 856/ n =107/ T = 8
		Sub-loop access	.240	.427	0	1	N = 856/ n = 107/ T = 8
		Entry regulation	2.495	1.807	0	6	N = 856/ n = 107/ T =8
		Interconnection regime	.746	.320	0	1	N = 856/ n = 107/ T = 8
		Transparency of interconnection agreements	.484	.500	0	1	N = 856/ n = 107/T = 8
		Transparency of interconnection price	.699	.458	0	1	N = 856 /n = 107/ T = 8
		Market transparency	1.184	.842	0	2	N = 856/ n = 107/ T = 8
		Status of SMP operator	.272	.445	0	1	N = 856/ n = 107/ T = 8
(2)		Regulatory autonomous decision	.8644	.342	0	1	N = 856 /n = 107/ T = 8
		Overall reform	5.562	2.454	0	10	N = 856/ n = 107/ T = 8
		Overall reform index	.505	.223	0	.909	N = 856 /n = 107/ T = 8
		Entry reform index	.415	.301	0	1	N = 856 /n = 107/ T = 8
		Ln(GDPpc)	8.326	1.542	5.458	11.590	N = 838 / n=106 /T = 7.9
		Ln(Population)	15.986	2.022	10.44	21.019	N = 856/ n=107/ T=8
		School enrollment secondary	85.267	24.765	10.82	149.83	N = 636/ n=102/T-bar = 6.2
		School enrollment tertiary	42.916	24.532	1.176	95.072	N = 563/ n=97/ T-bar = 5.8
		Urban population	62.256	21.416	13.01	100	N =856/ n = 107/ T = 8
		Age	64.898	5.974	48.65	85.52	N =824/ n=103/T=8
		Main tel. lines per 100 people	25.203	19.979	.167	99.049	N = 850/n=107/ T = 7.94393
(3)		Internet users (per 100 people)	36.005	27.411	.199	95.02	N = 841/n = 107/ T-bar =7.859
		Regulatory Quality	.369	.891	-2.210	1.931	N = 847/n = 106/ T-bar =7.990
		Voice and Accountability	.212	.960	-1.843	1.826	N =856/ n = 107/ T =8
		Europe & Central Asia (WB)	.157	.364	0	1	N = 856/ n =107/ T =8
		High income: Non OECD (WB)	.235	.424	0	1	N = 856/ n =107/ T = 8
		High income: OECD (WB)	.133	.339	0	1	N = 856/ n =107/ T =8
		Middle East & North Africa (WB)	.078	.268	0	1	N = 856/ n = 107/ T =8
		Latin America & Caribbean (WB)	.170	.376	0	1	N = 856/ n =107/ T = 8
		East Asia & Pacific (WB)	.065	.247	0	1	N = 856/ n = 107/ T = 8
	1	Sub-Saharan Africa (WB)	.112	.315	0	1	N = 856/ n = 107/ T = 8
		South Asia (WB)	.046	.211	0	1	N = 856/ n = 107/ T = 8
	2	OPEP	.074	.263	0	1	N = 856/ n = 107/ T = 8
	3	Non- OECD	.731	.443	0	1	N = 856/ n = 107/ T = 8
	4	Non-EU countries	.764	.424	0	1	N = 856/ n = 107/ T = 8
	5	Developing countries (IMF)	.742	.437	0	1	N = 856/ n = 107/ T = 8
(4)	**6**	Developing countries (UN)	.654	.475	0	1	N = 856/ n = 107/ T = 8
		High income (WB)	.369	.482	0	1	N = 856/ n = 107/ T = 8
		Upper-Middle income (WB)	.240	.427	0	1	N = 856/ n = 107/ T = 8
	7	Low-Middle-income (WB)	.241	.428	0	1	N = 856/ n = 107/ T = 8
		Low-income (WB)	.143	.350	0	1	N = 856/ n = 107/ T = 8

Figure A. **Evolution of Fixed Broadband Subscriptions per 100 people over 2004-2011**

Countries grouped by income level

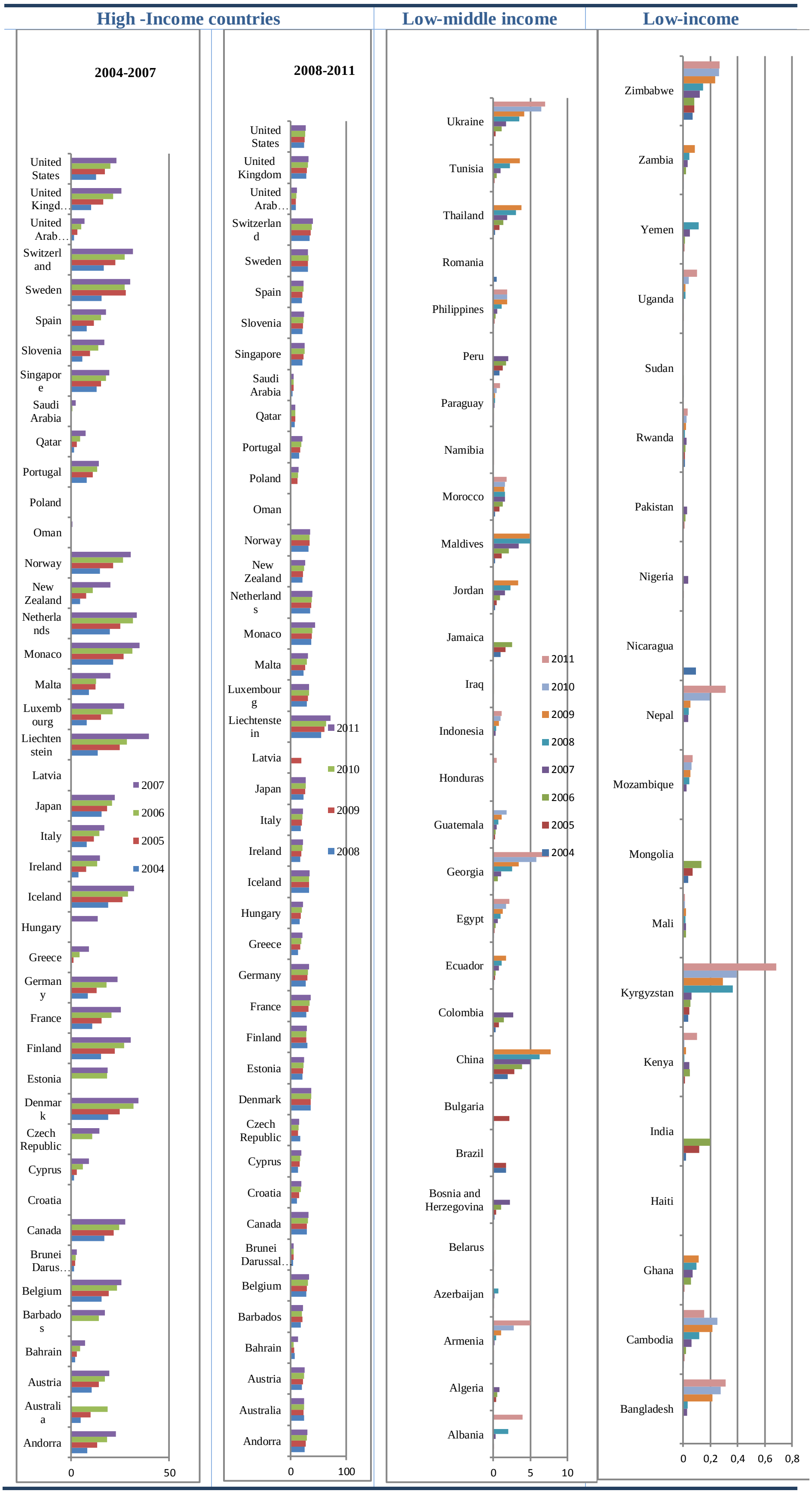


Figure B. **Evolution of Overall regulation measure over countries**

High-income countries (grouped as OECD & non-OECD)/ other countries (grouped by region)

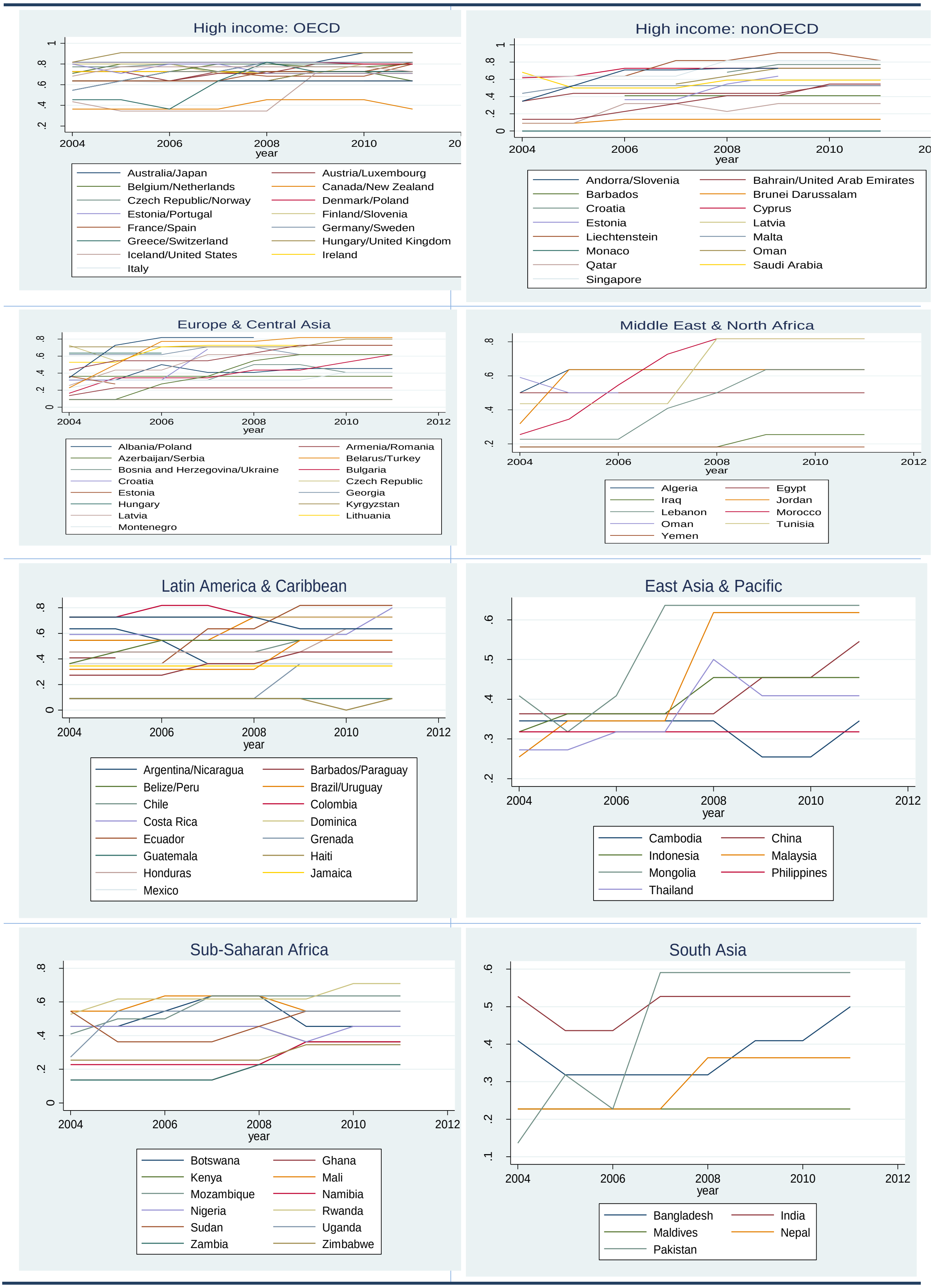
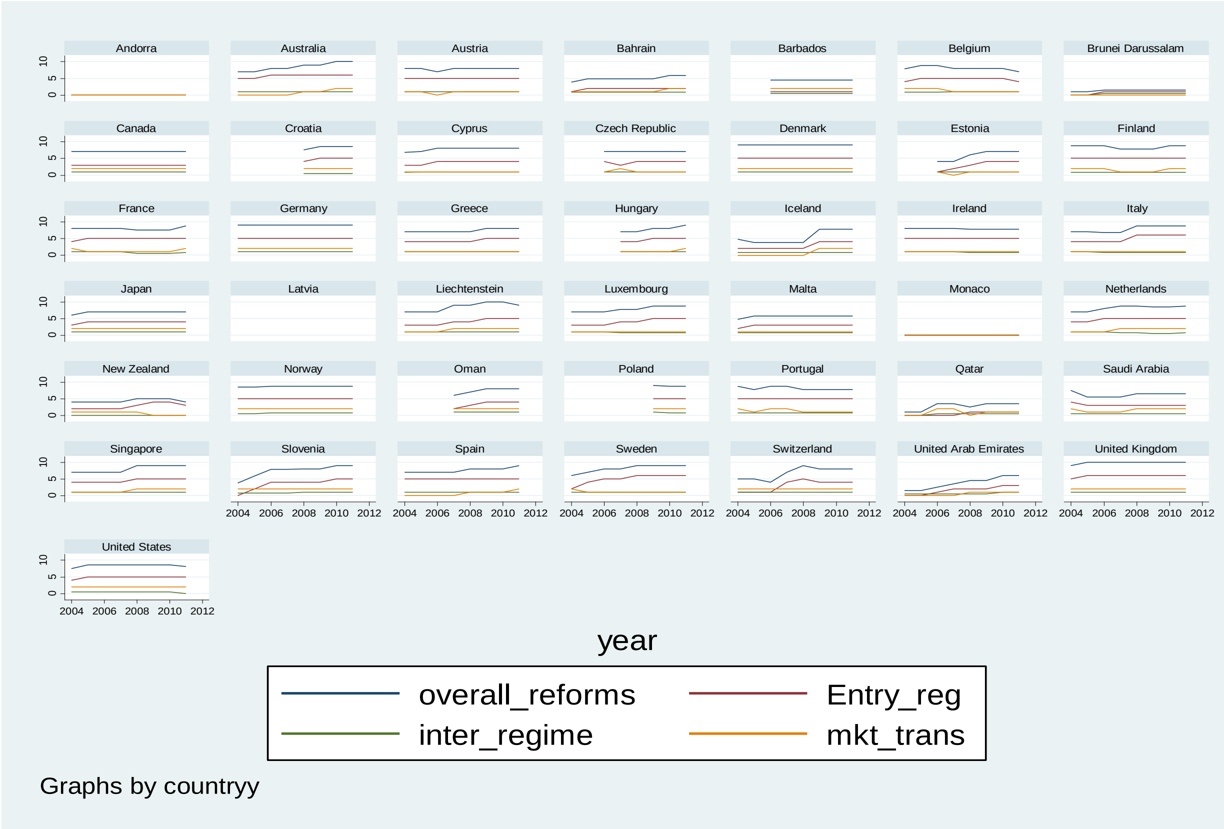


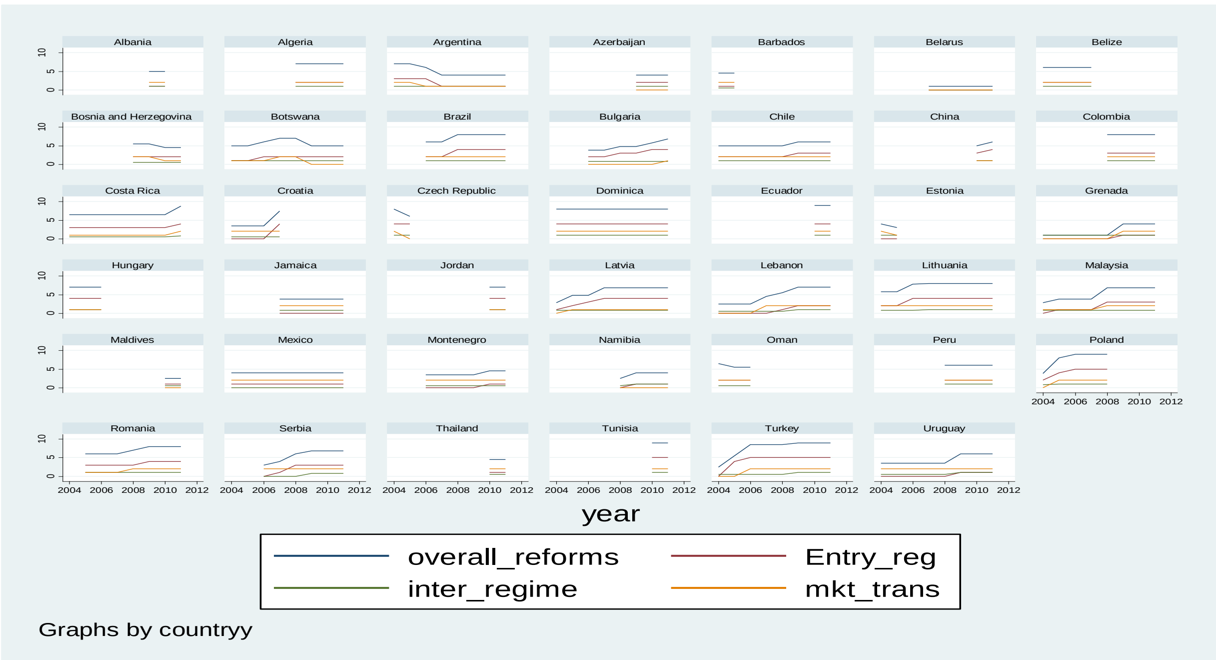
Figure C. **Evolution of regulation measures over period 2004-2011 (by country)**

Classification by level of income

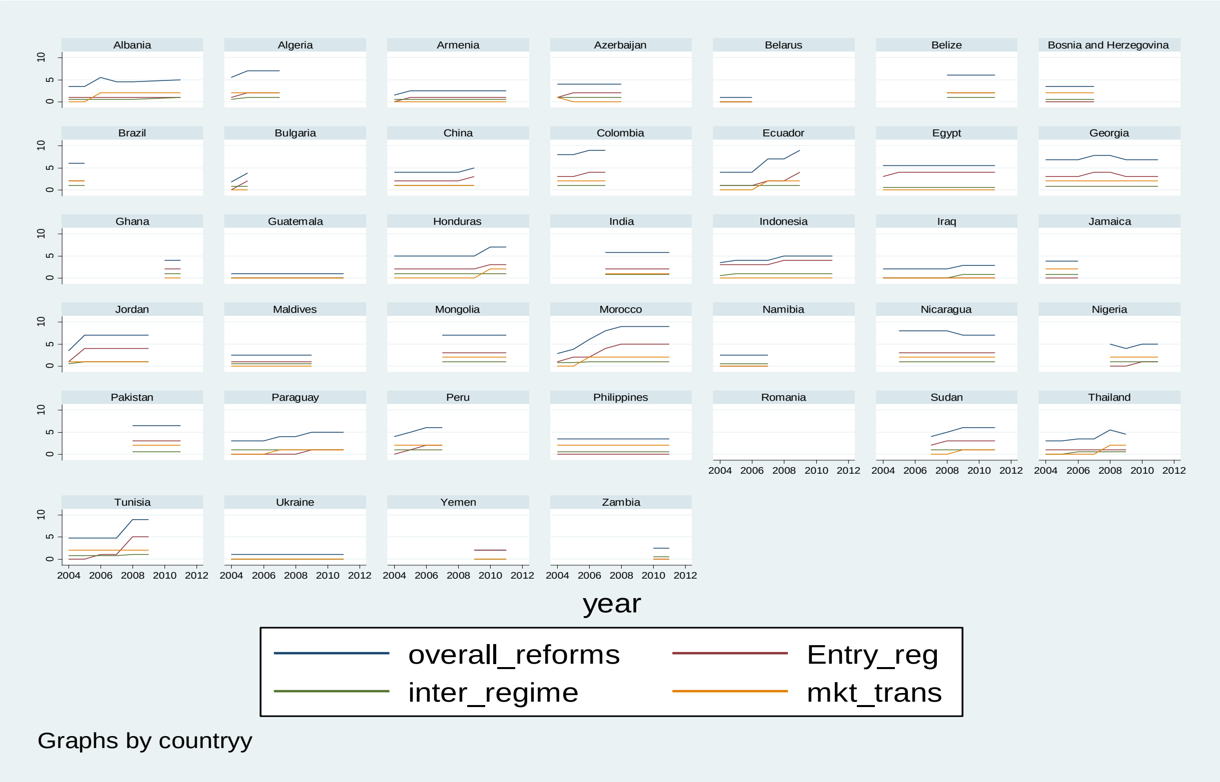
Graph 1 : High Income Countries



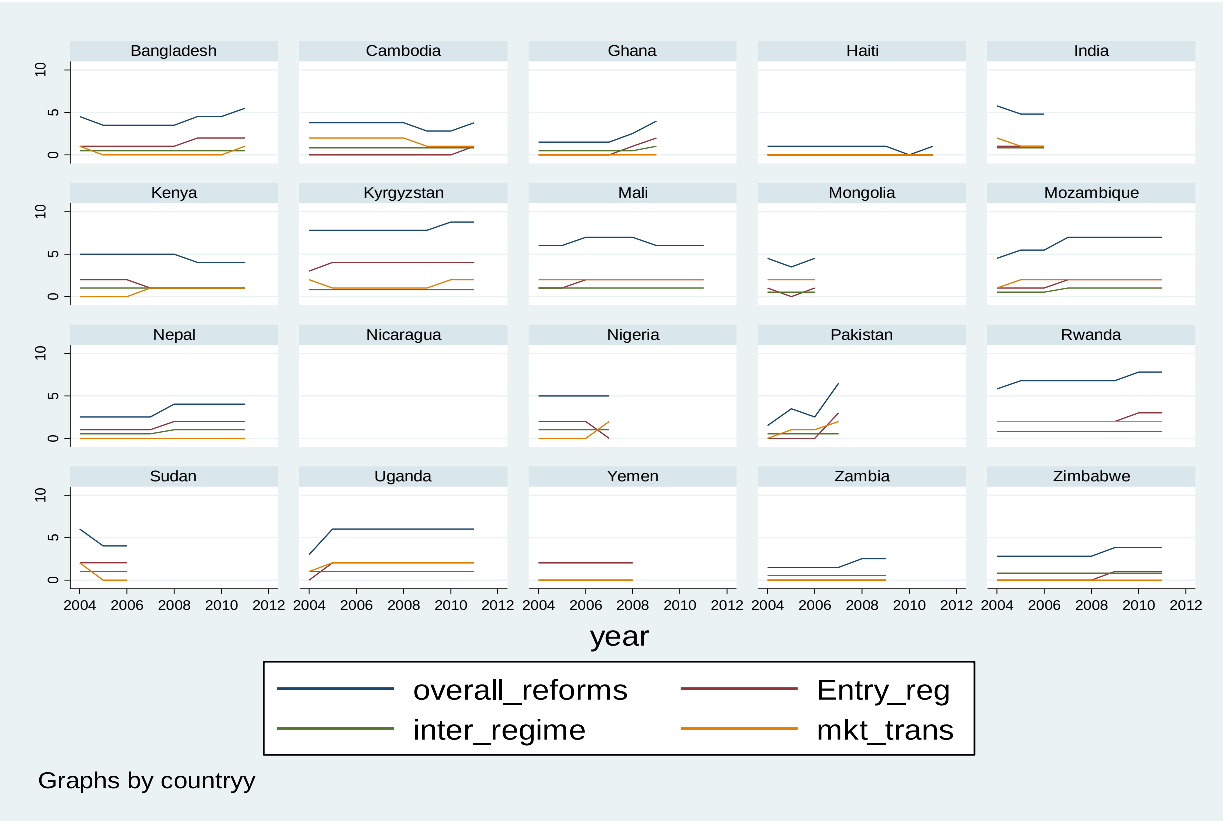
Graph 2 : Upper-Middle Income Countries



Graph3 : Low-Middle Income Countries



Graph 4 : Low Income Countries



A Summary of the econometric methodology

Multi-collinearity tests

(Results: In general, according to VIF values, no problem of multi-collineariry detected
However, there are possibly problems of multi-collinearities between GDP & other controls (except population) given the high values of coefficients of correlation.)

⇓

(we assume that OLS hypothesis hold)

OLS regressions

Diagnostics:

Unpredicted signs of estimates of controls that have correlated with GDP_{pc}
F-tests: models are globally significant
Ramsey Reset tests: there are problems of misspecification and omitted variable in regressions that include lagged dependent variables
Low R-squared in certain cases

Conclusion

We should take into account unobserved heterogeneities
OLS estimator is not appropriate for dynamic models Baltagi (2005, p.135 and p.13).

⇓

Preliminary & post estimation Tests

Breusch-Pagan Lagrange Multiplier test (B-PLM test) : (Conclusion: Random effects estimator is better than OLS estimator)
Hausman test: (Conclusion: Fixed effects estimator is better than OLS estimator
The "modified Wald test for group-wise heteroskedasticity": (conclusion: there is a problem of heteroskedastic errors)
Wooldridge tests for serial correlation: (conclusion: there is a problem of autocorrelated errors)
Robust Hausman test (to take into account problem of heteroskedastic and autocorrelated erros):
Wald test (for year dummies):

Robust fixed effects with cluster on countries (year dummies included)

Diagnostics:

Including fixed effects results in high R-squared compared to R-squared of OLS regressions
Yet, we obtain unpredicted signs of estimates of controls thatwe have doubt their possible correlation with GDP_{pc} (which confirm the multi-collinearity between controls, except population)
Fixed effects estimator is also not appropriate for dynamic models.

⇓

IV/GMM methods (2SLS, 2S- GMM, GMM-CUE) with fixed effects robust to heteroskedastic and autocorrelated errors (year dummies included)

(These methods are used to control for reverse causality between regulatory variables and broadband deployment. These methods also permit better results for dynamic models compared to usual methods (OLS with and without fixed effects))

N.B.: 2SLS is a specific case of GMM that provide better results than 2S-GMM and GMM-CUE when instruments are strong, number of observations is important (exceed 700 observations) and there is no problem of heteroskedastic and autocorrelated errors.
2S-GMM is better than 2SLS and GMM-CUE when there are problem of heteroskedastic and autocorrelated errors.
GMM-CUE is better when instruments are weak and number of observations is low enough.

Preliminary and post-estimations tests

(Hausman tests for IV, Pagan-Hall IV heteroskedasticity test, Endogeneity tests for set of endogenous regressors (Durbin-Wu-Hausman), F-tests of first stage, F-tests of excluded instruments, The Angrist-Pischke (AP) first-stage chi-squared (tests of under-identification), Angrist-Pischke multivariate F test of excluded instruments: (tests of weak identification), Weak identification test (Cragg-Donald Wald F statistic & Kleibergen-Paap Wald rk F statistic), The underidentification test (Kleibergen-Paap rk LM statistic), Weak-instrument-robust inference tests (Anderson-Rubin (1949) test & Stock-Wright (2000) test), IV redundancy test (LM test of redundancy of specified instruments), Hansen J test (Sargan-Hansen test of over-identifying restrictions))
These tests confirm the choice of these methods and the consistency of our estimation results.

Table B: Year dummies (estimates)

Specification	**Estimation Method**	**Estimate Coefficients for respectively years: 2005, 2006, 2007, 2008, 2009, 2010 (with corresponding robust standard errors)**
A	IV-2SLS	1.91***(0.474), -0.65***(0.088),-0.43***(0.071), -0.33***(0.063),-0.15**(0.062), -0.083^{+}(0.053)
	2S-GMM	1.91***(0.474), -0.65***(0.088),-0.43***(0.071), -0.33***(0.063),-0.15**(0.062), -0.082^{+}(0.053)
	CUE-GMM	1.91***(0.474), -0.65***(0.089),-0.43***(0.071), -0.33***(0.063),-0.15**(0.062), -0.082^{+}(0.053)
B	IV-2SLS	1.95***(0.506),-0.68***(0.092),-0.44***(0.076), -0.31***(0.065), -0.14**(0.067),-0.081^{+}(0.055)
	2S-GMM	1.87***(0.489),-0.68***(0.091),-0.45***(0.074), -0.31***(0.065), -0.15**(0.066),-0.084^{+}(0.055)
	CUE-GMM	1.86***(0.484),-0.68***(0.090),-0.45***(0.074), -0.31***(0.065), -0.15**(0.066),-0.085^{+}(0.055)
C	IV-2SLS	1.59***(0.411),-0.75***(0.086),-0.50***(0.074), -0.36***(0.063), -0.17**(0.062),-0.0981*(0.054)
	2S-GMM	1.58***(0.411),-0.75***(0.086),-0.50***(0.074), -0.36***(0.063), -0.17**(0.062),-0.0981*(0.054)
	CUE-GMM	1.58***(0.410),-0.75***(0.086),-0.50***(0.074), -0.36***(0.063), -0.17**(0.062),-0.097*(0.054)
D	IV-2SLS	1.51***(0.449),-0.75***(0.097),-0.48***(0.083), -0.35***(0.069), -0.16***(0.066),-0.094^{+}(0.057)
	2S-GMM	1.56***(0.444),-0.75***(0.096),-0.48***(0.080), -0.34***(0.068), -0.17***(0.065),-0.089^{+}(0.057)
	CUE-GMM	1.55***(0.447),-0.75***(0.097),-0.48***(0.082), -0.34***(0.070), -0.17***(0.066),-0.089^{+}(0.058)
I	IV-2SLS	1.55***(0.426),-0.74***(0.087),-0.49***(0.071), -0.39***(0.063), -0.206***(0.061),-0.010*(0.053)
	2S-GMM	1.55***(0.426),-0.74***(0.087),-0.49***(0.071), -0.39***(0.063), -0.207***(0.061),-0.010* (0.053)
	CUE-GMM	1.55***(0.426),-0.74***(0.087),-0.49***(0.071), -0.39***(0.062), -0.207***(0.061),-0.010* (0.053)
II	IV-2SLS	1.53***(0.440),-0.75***(0.089),-0.50***(0.072), -0.39***(0.062), -0.19***(0.060),-0.010*(0.053)
	2S-GMM	1.54***(0.440),-0.74***(0.089),-0.49***(0.072), -0.38***(0.062), -0.18***(0.060),-0.096*(0.052)
	CUE-GMM	1.63***(0.440),-0.73***(0.09),-0.48***(0.072), -0.37***(0.062), -0.17***(0.060),-0.092*(0.052)
III	IV-2SLS	1.33***(0.448),-0.74***(0.089),-0.48***(0.072), -0.36***(0.067), -0.17**(0.060),-0.011**(0.054)
	2S-GMM	1.36***(0.448),-0.72***(0.089),-0.47***(0.071), -0.34***(0.066), -0.16**(0.064),-0.011**(0.054)
	CUE-GMM	1.31***(0.448),-0.72***(0.087),-0.47***(0.070), -0.34***(0.066), -0.16**(0.064),-0.011**(0.054)

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